Worthing Civic Quarter Network Feasibility Report

Worthing Borough Council

Project Number: 60630054

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Quality information

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Revision History

Revision	Revision date	Details	Name	Position
0	19/06/20	Draft for comment	Sam Shuttleworth	Energy Engineer
1	16/07/20	Final issue for comment	Sam Shuttleworth	Energy Engineer
2	07/08/20	Final issue	Sam Shuttleworth	Energy Engineer
3	28/08/20	Heat mapping study results updated	Sam Shuttleworth	Energy Engineer

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Executive Summary

The Adur and Worthing Council Carbon Neutral Plan, published December 2019, identified that the key actions and interventions required for the council to meet their net zero carbon emissions by 2030 target. One of the key measures was the need to transition all existing heating systems, most of which use gas boilers, to lower carbon systems, with District Energy Networks recognised as a possible part of the strategy to achieve this goal.

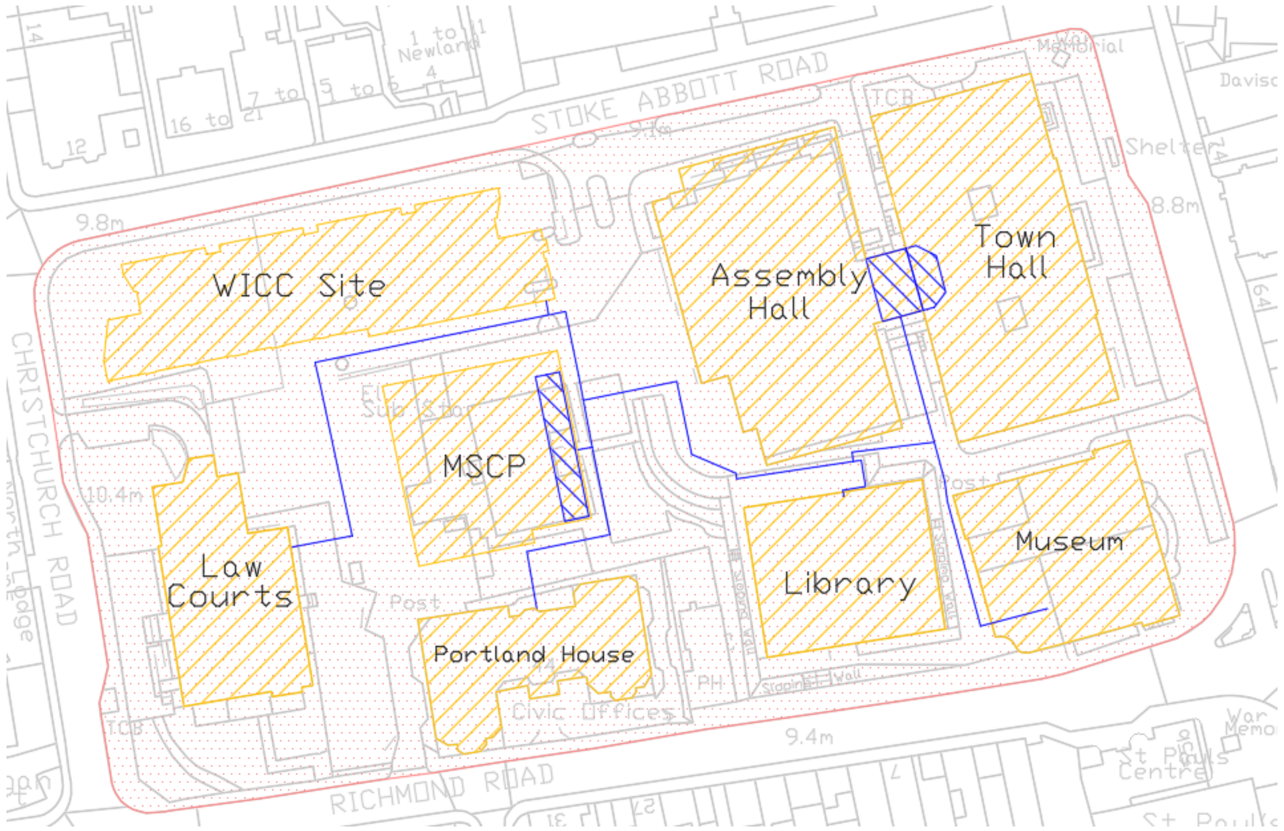
Given the anticipated continued decarbonisation of the UKs electrical grid, the utilisation of electrically fuelled heat pump systems can facilitate this transition. This can be achieved in one of two ways:

- Via replacement of gas boilers within each building with heat pumps, with air source systems typically being the most deliverable solution; or
- Via the creation of a heat-pump led district heating network.

The aim of this heat techno-economic feasibility study is to identify the potential for a district level system within the Civic Quarter in Worthing. This area contains some key local authority owned buildings as well as other publicly owned estate. Given the proximity of the buildings and the upcoming development of the Worthing Integrated Care Centre, the potential for a low carbon district energy network solution was highlighted in the carbon neutral plan.

The key steps taken to conduct this analysis were:

1. Building energy demand and existing system data collected;
2. Centralised energy centre locations assessed;
3. Low / zero carbon generational technologies assessed;
4. Modelling assessment to identify optimal solution; and
5. Concept designs produced.



Concept district energy network design for a system serving the Civic Quarter.

The two most suitable solutions identified were:

- **Solution 1:** An open loop ground source heat pump array installed within the WICC development boundary, abstracting and reinjecting ground water from the chalk aquifer beneath the Civic Quarter site. This solution offers CO_2 reductions of 75% (min.), as generational capacity may be constrained by the available groundwater yield from a single borehole (to be confirmed via testing); or
- **Solution 2:** A sewer source heat pump system, capturing waste heat from the sewer system running adjacent to the Union Place development site, 200 metres east from the Civic Quarter. This solution offers CO_2 reductions of up to 90%, as the flow within the sewer is estimated to be high enough to meet all the site's heat requirements.

The potential for a large-scale network serving numerous new developments and existing sites across the wider Worthing area was also investigated. The optimal solution for such a network was identified as being an extended version of Solution 2 above, being based upon a system utilising a large-capacity sewer source installation initially with additional generational capacity from a ground source heat pump installation added as the network expands.

	Building level ASHP installations	Solution 1; Ground source heat pump	Solution 2; Sewer source heat pump	Extended network; Sewer and ground source heat pump
Network Scope	Civic Quarter Only	Civic Quarter Only	Civic Quarter & Union Place	Worthing-wide
Capital cost[1]	£1.3m	£1.9m	£4.3m	Up to £16.3m
Levelised cost of heat	15.2 p/kWh	8.7 p/kWh	11.3 p/kWh	9.2 p/kWh
CO_2 reduction versus present day systems	14,100 tonnes 87% total reduction	12,200 tonnes (min.)[2] 75% total reduction	22,500 tonnes 90% total reduction	170,300 tonnes 85% total reduction

Decarbonisation project performance factors

When compared to building level heat pumps, the benefits of the proposed district energy network solutions are:

- Reduced whole life cycle costs (represented by the levelised cost of heat), resulting in lower customer capital and operational heating costs;
- The potential for larger reductions in CO_2 emissions as higher efficiency heat pump systems can be utilised;
- Being a single project that can decarbonise the heating within all buildings on the Civic Quarter site in one go and at an earlier date, resulting in lower over CO_2 emissions in the short term;
- The implementation and maintenance of a low carbon heating solution becomes the responsibility of a specialist Energy Supply Company, and not of the individual building operators, likely meaning more effective operation; and
- Promoting job growth in the local area.

It is therefore concluded that **<u>the potential for delivering a heat network on the Civic Quarter site is high</u>** and the project should be further developed to facilitate the council's building stock in the area becoming carbon neutral.

[1] The capital costs shown for all solutions include an allowance to undertake the required adaptation works to lower internal heating system operational temperatures (within the 6 existing Civic Quarter buildings).

[2] The actual achievable CO_2 savings for a ground source heat pump solution could be higher than those presented, should sufficient groundwater yield be obtainable.

1. Introduction

On July 9th, 2019 the Joint Strategic Committee of Adur & Worthing Councils (A&WC) declared a Climate Emergency and committed to working towards becoming carbon neutral by 2030, and in support of this declaration, on December 9th, 2019 the Carbon Neutral Plan was published[3].

This plan identifies the key actions and interventions required for the councils to meet their net zero carbon emissions target[4]. One of the key measures was the need to transition all existing heating systems, most of which use gas boilers, to lower carbon systems. This was acknowledged to be a challenge but opportunities for projects to deliver this were identified, including the potential within the Civic Quarter site.

The Civic Quarter contains some key A&WC owned buildings as well as other publicly owned estate. Given the proximity of the buildings and the upcoming development of the Worthing Integrated Care Centre (WICC) in the north-west corner of the site, the potential for a low carbon District Energy Network (DEN) solution was highlighted. This presents the opportunity for a single intervention to deliver low carbon heat to multiple buildings in a way that should be quicker and more effective than building-by-building approach.

Following on from the completion of the Carbon Neutral Plan, AECOM were subsequently commissioned to undertake a Techno-Economic Feasibility study looking at the viability for a DEN serving the entire 'Civic Quarter' area in Worthing. This report forms the key deliverable for the study which has been completed in line with the Heat Network Delivery Unit (HNDU) guidelines.

The redline boundary for this study is indicated in the figure below. Once the WICC development is completed, the Civic Quarter site shall contain 7 buildings and a Multi-Story Car Park (MSCP), all of which will be owned and operated by public bodies – these buildings shall form the primary analysis within this report.

There is an additional multiple-use development site - 'Union Place' - located 180m from the Civic Quarter boundary. It is currently owned by A&WC and is anticipated to be sold and delivered by the private development market in 2 phases between 2021 – 2025. Use of this site, either as a potential location for District Energy Network (DEN) plant, and / or as a potential energy customer, shall be considered as part of a secondary 'sensitivity' analysis.

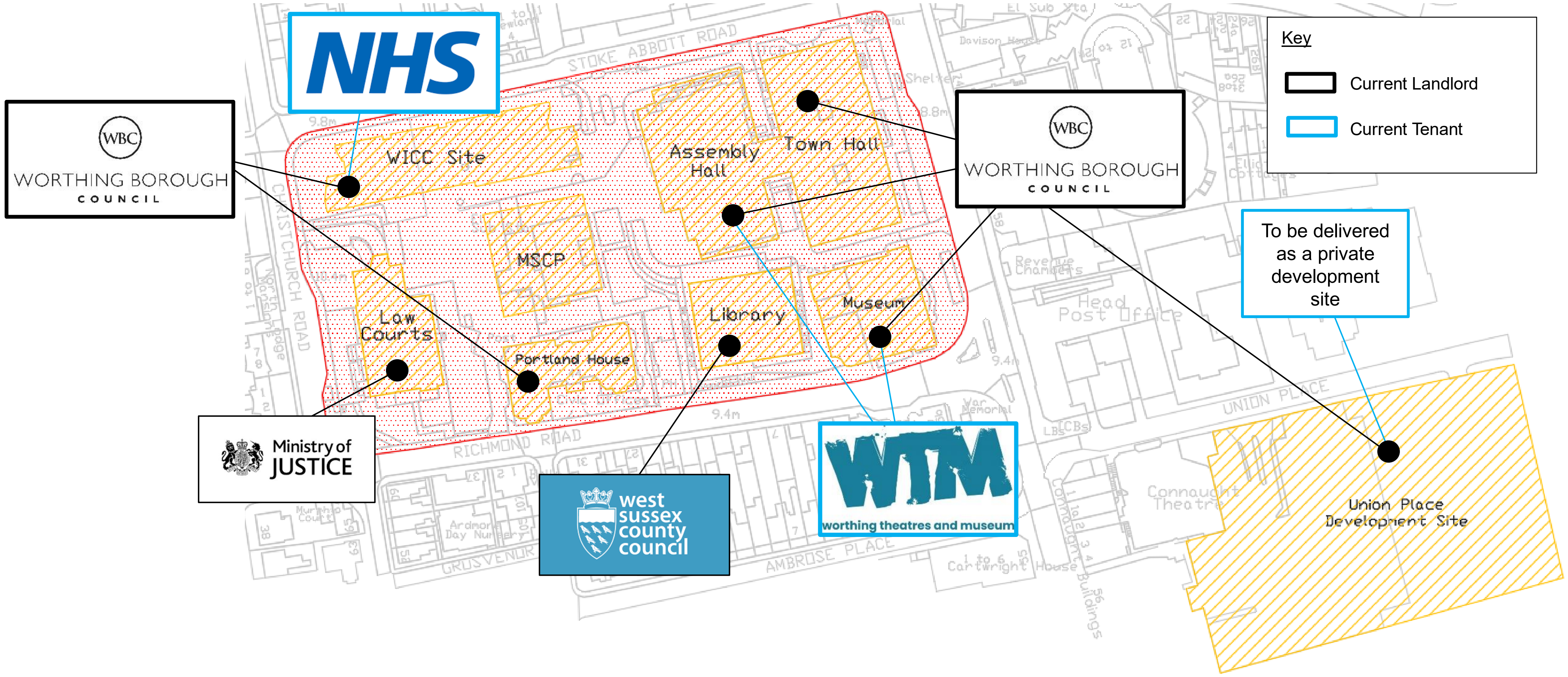


Figure 1-1: Map of the Civic Quarter Area in Worthing, showing the location and key stakeholders for the operation of each building

This study is being delivered in parallel to a Heat Mapping & Masterplanning (HM&MP) study, looking into the potential for both the potential expansion of any Civic Quarter DEN beyond the Civic Quarter site and potential for additional DENs across the entire Worthing Borough. Outcomes from this HM&MP study shall be discussed within this report where appropriate.

[3] Carbon Neutral Plan prepared by AECOM for Adur & Worthing Council. Published online: https://www.adur-worthing.gov.uk/media/Media,156218,smxx.pdf

[4] The Carbon Neutral Plan primarily investigated Adur & Worthing Councils Scope 1 & Scope 2 carbon emissions, with additional consideration of Scope 3 emissions. Scope 1 carbon emissions are termed as direct emissions from sources owned or controlled by the reporting organisation. Scope 2 carbon emissions are indirect emissions from the generation of energy purchased by the reporting organisation. Scope 3 are indirect emissions that result from other activities that occur in the value chain of the reporting organisation, either upstream or downstream.

2. Building Data

2.1 Stakeholder Engagement and Data Obtained

As the majority of the project was undertaken during April to July 2020 during the global Covid-19 pandemic, no additional building internal surveys were conducted, therefore all information gathered was done so through remote contact with the different stakeholders. For full details on what information was collected, refer to Appendix A. Where data was either unavailable due to limitations surround site access or staff absences, benchmark data developed by AECOM for the purposes of analysing DEN schemes shall be used. These assumptions are detailed in Appendix I.

The following table details the key information that was obtained by AECOM during the undertaking of this project.

Building	Current Heating Generation Plant	Current Cooling Generation Plant	Planned Refurbishment
Town Hall	Gas boilers and calorifier (serving whole site)	Small VRV split units (serving isolated offices and IT server rooms)	Installation of extra secondary glazing throughout Replacement of gas boilers
Assembly Hall	Gas boilers and calorifier (serving whole site)	None	Replacement of gas boilers
Portland House	Gas boilers and calorifier (serving whole site)	Small VRV split units (serving isolated offices and IT server rooms)	Repair or replacement of glazing
Museum and Art Gallery	Gas boilers, gas calorifier and VRV split units distributed across the site	VRV split units	'Let the Light In' Project – Building extension and reconfiguration
Library	Gas boilers and calorifier (serving whole site)	Centralised chiller system, scope of supply TBC	HVAC system refurbishment
Law Courts	Gas boilers and calorifier (serving whole site)	Centralised chiller system, scope of supply TBC	None
WICC	Air Source Heat Pumps (serving whole site)	Air Source Heat Pumps	N/A, site to be developed
Union Place	Air Source Heat Pumps (serving whole site)	Air Source Heat Pumps (serving whole site)	N/A, site to be developed

Table 2-1: HVAC system details and upcoming refurbishment plans

All the existing sites identified have centralised hot water-based heating systems that are suitable for connection to a District Heating (DH) scheme. Furthermore, the Library, Law Courts and WICC development site also had centralised cooling systems, which would also be suitable for connection to a District Cooling (DC) scheme.

An existing private-wire network also exists, with incoming power into the Town Hall substation serving the Town Hall, Assembly Hall and Law court sites. As such, any technical option analysed that includes an element of power generation (e.g. from Combined Heat and Power Plant, CHP) could utilise this network to export generated power to these 3 sites.

2.2 Energy Demand

The table below details the annual energy demand, by type, for each of the buildings in the Civic Quarter.

Building	Current Heating Demand, MWh/year	Current Cooling Demand, MWh/year	Current Power Demand, MWh/year*
Town Hall	621**	0	620
Assembly Hall	369**	0	*See Town Hall*
Portland House	181	0	154
Museum and Art Gallery	202	72*	40
Library	153	110*	190
Law Courts	350	91*	*See Town Hall*
WICC	308	36*	TBC
Total	**2,184**	**309**	**1,004**

Table 2-2: Energy demands for the Civic Quarter buildings.

* Current power demand figures have had estimated power requirements from cooling systems removed.

**Consumption values derived from energy benchmarks in lieu of accurate operational data being available.

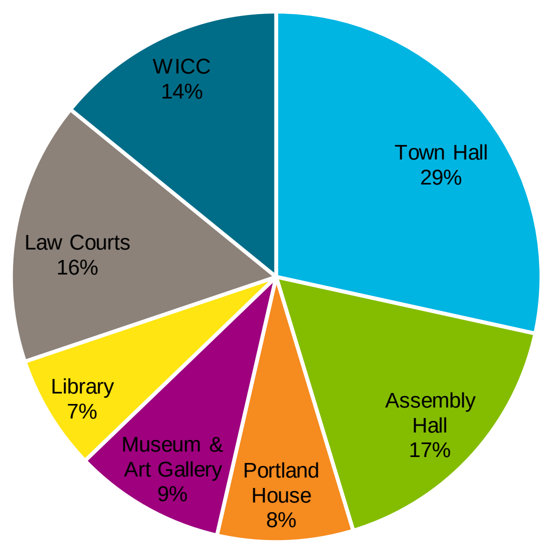


Figure 2-1: Building heat demand as a % of total Civic Quarter heat demand

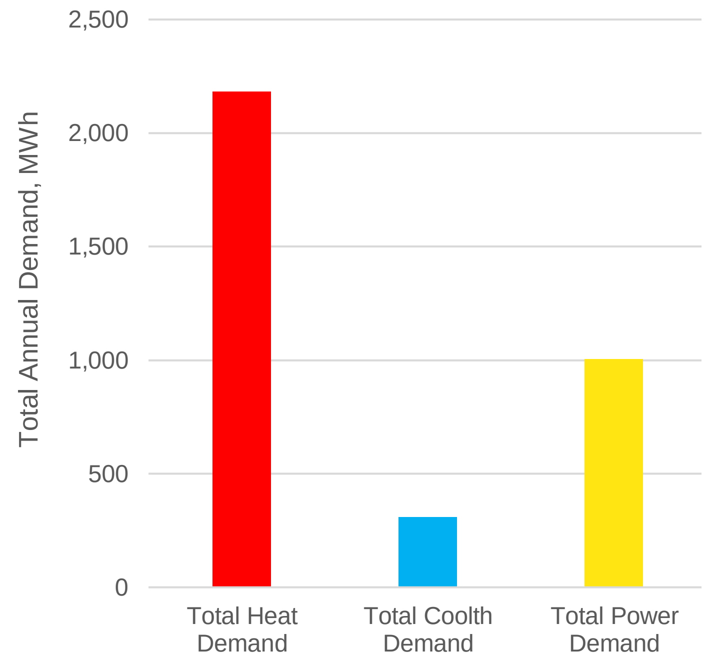


Figure 2-2: Total energy demand within the Civic Quarter

Figure 2-1 shows that the majority of the heat demand in the Civic Quarter is from the Town Hall and Assembly Hall, and Figure 2-2 shows that the total heat demand is substantially greater than the cooling and power demands.

For full details of the energy data collected and benchmarks used, refer to Appendix B.

2.3 Whole Life Cycle Cost of Heat and Counterfactual Future Energy Scenarios

To assess the techno-economic viability of a DEN project, the consideration of the counterfactual (or Business as Usual, BaU) energy generation and delivery scenario is critical as it will determine:

- the maximum energy tariff level that can be applied to prevent any customer paying more for energy (be it heating, cooling and/or power) than they would otherwise (i.e. preventing 'customer detriment'); and
- the level of carbon savings that the implementation of any DEN can offer.

For this project, three distinct counterfactual positions are to be investigated to demonstrate the potential impact they can have over the technical and economic solution. These are:

1) **Do nothing scenario;** Continue with the present-day energy generation and delivery strategies;
2) **Pay to be dirty scenario;** Continue with the present-day energy generation and delivery strategies with additional consideration of the cost to society in terms of the non-traded cost of carbon and air quality damage; or
3) **Pay to be clean scenario;** Consider a future scenario which considers the commitment to becoming carbon neutral by 2030.

Under all these counterfactual positions, the energy heating technologies differ on a building by building basis based upon their energy requirements. To estimate the comparative running costs of these different heating generation systems, a Whole Cycle Cost of Heat (WLCoH) analysis was conducted[5] for each site under all 3 scenarios, giving a pence per kilo watt hour value for each system. This value represents the time adjusted cost of energy generation and delivery over the whole life span of the project and can be used as a comparative metric when assessing different technologies. The output of this assessment is detailed below:

Building	Heating Plant Present	Present Day Tariff ('Do Nothing' Scenario) p/kWh	Present Day Tariff, with additional allowances for social cost ('Pay to be dirty' scenario), p/kWh	Equivalent ASHP Tariff ('Pay to be clean' Scenario), p/kWh
Town Hall	Gas boiler and calorifier	6.22	8.83	9.46
Assembly Hall	Gas boiler and calorifier	7.74	10.16	20.82
Portland House	Gas boiler and calorifier	6.46	8.86	13.53
Museum and Art Gallery	Gas boiler, calorifier and VRV units	7.35	9.79	24.53
Library	Gas boiler and calorifier	5.80	8.23	23.09
Law Courts	Gas boiler and calorifier	6.22	8.83	9.46
WICC	Air source heat pump	10.27	n/a	n/a

Table 2-3: Counterfactual heating plant scenarios and estimated WLCoH values

The WLCoH values of heat generation for the buildings are highly dependent on the size and utilisation rates[6] of the of the installed plant, with higher utilisation rates resulting in smaller per-unit tariffs. The WLCoH is typically lower for gas-based systems in comparison with electrically based, primarily due to the gas unit costs being typically 60-70% lower than electricity (as well as differences in capital and maintenance costs). However, this is not the case for the Town Hall and Assembly Hall plant, as the capital budget supplied by A&WC for the replacement of the boiler systems (£200,000, equating to £833 / kW) being higher than an equivalent ASHP installation (£700 / kW)[7].

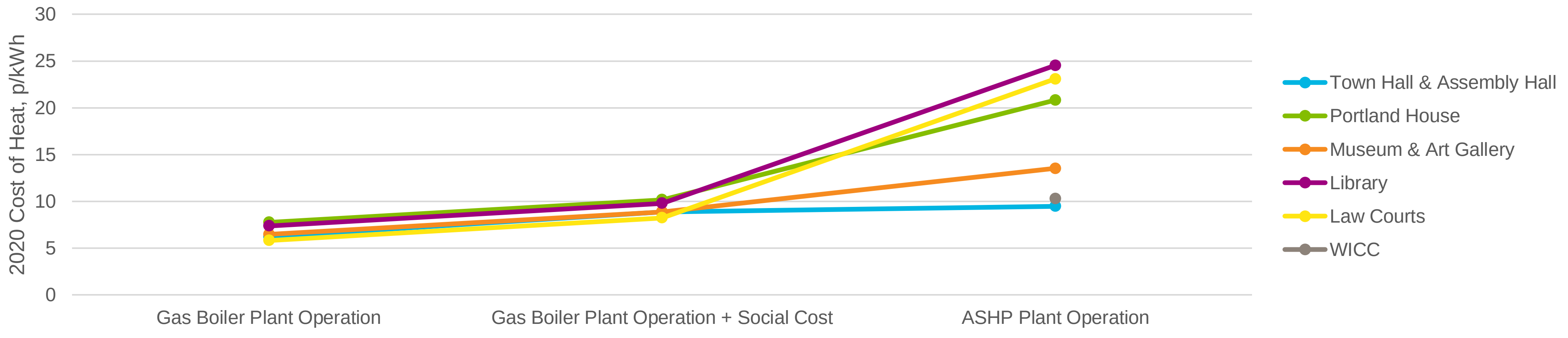


Figure 2-3: Graphical representation in the BaU heat tariff when considering the three different scenarios

[5] The WLCoH analysis was conducted using the BEIS Whole Life Cycle Cost of Energy (WLCoE) calculation tool
[6] The utilisation rate of generational plant is termed as the Total Metered Output / Total Maximum Output.

[7] This could be a result of the supplied capital budget including additional costs beyond the replacement of the boiler plant (i.e. also including ancillary plant replacement). Confirmation of the full scope of works of the provided budget is required from WBC to better understand the present day heating costs within the Town Hall and Assembly Hall.

3. Energy Centre Location(s)

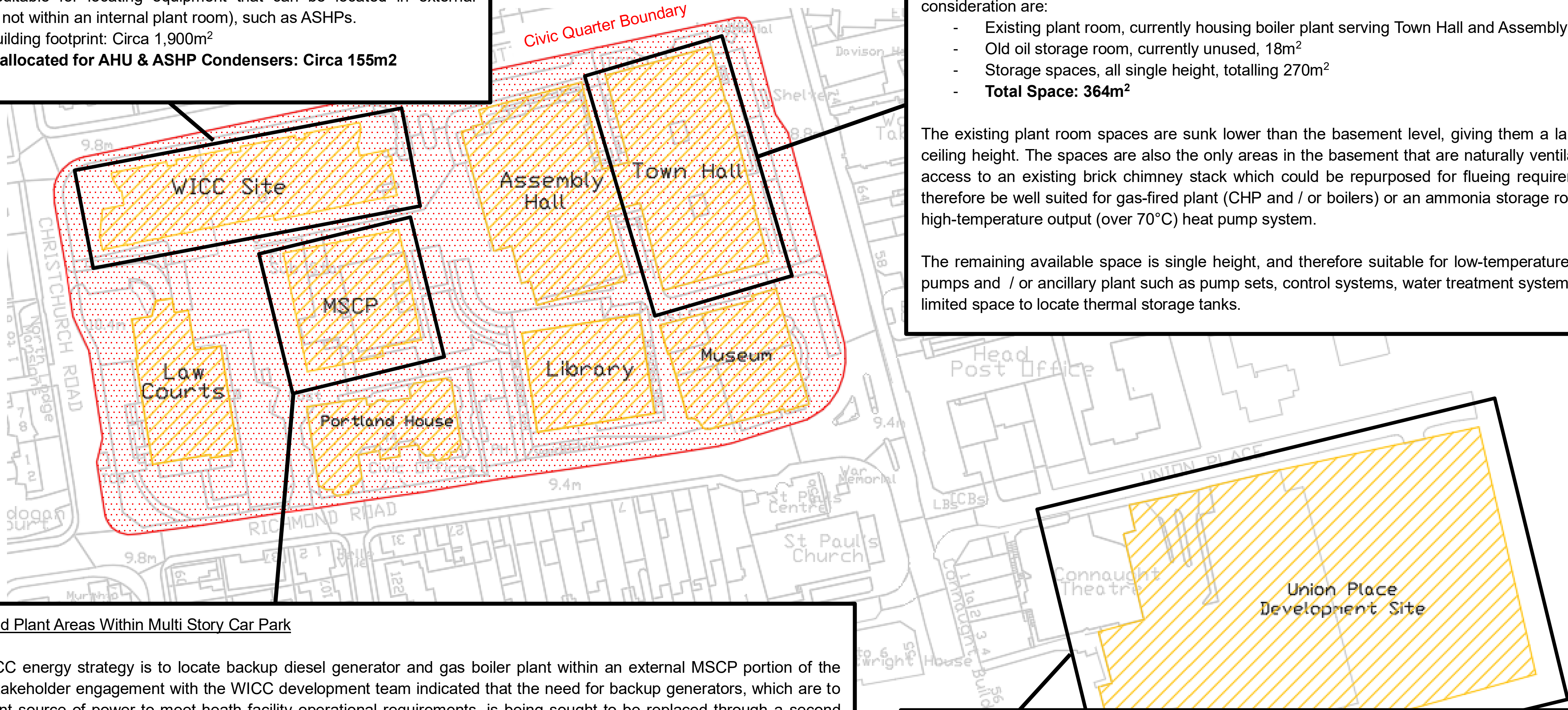
3.1 Potential Sites

The map below details the potential locations where centralised and distributed energy centres could be located across the project area.

<u>WICC – Care Centre Building Rooftop</u>

The current WICC energy strategy is to locate Air Source Heat Pump (ASHP) plant within acoustic enclosures on the rooftop of the clinic site. Initial engagement with the WICC development team has indicated that a larger provision of plant in this area could be acceptable for the purposes of serving a DEN, however planning constraints dictate that additional stories cannot be added to the building. This limits the space to being only suitable for locating equipment that can be located in external enclosures (e.g. not within an internal plant room), such as ASHPs.

- Total building footprint: Circa 1,900m^2
- **Space allocated for AHU & ASHP Condensers: Circa 155m2**



<u>Town Hall Basement Level Plant Room</u>

The basement within the Town Hall could be retrofit for the purposes of housing energy centre plant, with external access available directly into the existing plant room. The rooms that have been identified as available for consideration are:

- Existing plant room, currently housing boiler plant serving Town Hall and Assembly Hall; 76m^2
- Old oil storage room, currently unused, 18m^2
- Storage spaces, all single height, totalling 270m^2
- **Total Space: 364m^2**

The existing plant room spaces are sunk lower than the basement level, giving them a larger overall floor to ceiling height. The spaces are also the only areas in the basement that are naturally ventilated. There is easy access to an existing brick chimney stack which could be repurposed for flueing requirements. They would therefore be well suited for gas-fired plant (CHP and / or boilers) or an ammonia storage room for use within a high-temperature output (over 70°C) heat pump system.

The remaining available space is single height, and therefore suitable for low-temperature (under 70°C) heat pumps and / or ancillary plant such as pump sets, control systems, water treatment systems etc. There is very limited space to locate thermal storage tanks.

<u>WICC – Allocated Plant Areas Within Multi Story Car Park</u>

The current WICC energy strategy is to locate backup diesel generator and gas boiler plant within an external MSCP portion of the development. Stakeholder engagement with the WICC development team indicated that the need for backup generators, which are to provide a resilient source of power to meet heath facility operational requirements, is being sought to be replaced through a second UKPN grid connection.

During the outline planning permission application in May 2020, a single-story area was included within the designs. This design could be adapted to allow for a double height area, allowing for a mezzanine floor to house additional plant equipment for the purposes of a DEN. Should these alternations to the outline design occur, the following total floorspace will be available:

- Boiler room, 33m^2
- Generator room, 78m^2
- A potential mezzanine floor, c. 90m^2
- **Total available plant area: 201m^2**

As the site could be designed for the purpose of being used as an Energy Centre, it would be suitable for all types of equipment, including thermal storage tanks.

<u>Offsite Option - Union Place Development Site</u>

The 'Union Place' development site is currently Local Authority (LA) controlled. Outline planning permission is being sought for 185 dwellings, a 93-bed hotel, c. 400m^2 of commercial space and a 4-screen extension of the adjacent cinema. The site is due to be sold off to private developers in portions and delivered in 2 phases. Following early stakeholder engagement, the possibility of the LA to withhold a portion of the site for the purposes of a DEN were explored and the principle was notionally agreed upon as being possible. As the site could be designed for the purpose of being used as an Energy Centre, it would be suitable for all types of equipment, including thermal storage tanks.

- Total site footprint: c. 10,000 m^2
- **Total available plant area: TBC**

3.2 Location Appraisal

Based on the areas identified as being suitable to site an Energy Centre (EC), 4 potential solutions have been identified:

1) Utilise both the WICC allocated plant area in the MSCP in conjunction with the existing plant space in the Town Hall basement;
2) Locate all plant within the Town Hall basement area;
3) Utilise both the WICC roof-space and WICC allocated plant area in the MSCP for a solution that includes Air-Source-Heat-Pumps; or
4) Locate all plant off-site within a notional area within the Union Place development, located approximately 200m from the Civic Quarter site.

A qualitative assessment of the 4 different possible EC solutions is shown below. The table includes scoring rationale, highlighting the advantages and disadvantages of each option, and ranks them in order of suitability. Scoring is based on a comparative assessment of the options against the criteria with a 1 to 5 score and equal rating for each criterion.

	Option 1 WICC MSCP and Town Hall Plant Room		Option 2 Town Hall Basement		Option 3 WICC Roof-Space and MSCP		Option 4 Union Place Development	
Criteria	*Score*	*Rationale*	*Score*	*Rationale*	*Score*	*Rationale*	*Score*	*Rationale*
Plan Area Suitability	3	*Split site will require more pipework*	3	*Segregated site will require more pipework*	3	*Split site will require more pipework*	5	*Purpose built single area available*
Height Restrictions	5	*Sufficient clearance available*	3	*Limited double height space available*	5	*Sufficient clearance available*	5	*Sufficient clearance available*
Other Site Restrictions	3	*Plant movement access into Town Hall restrictive*	2	*Plant movement access into basement restrictive*	3	*Plant movement access onto roof-space restrictive*	3	*Noise constraints as adjacent to residential area*
Access	4	*Vehicular access to both sites available*	4	*Vehicular access to site available*	3	*Roof-space access through building*	3	*Vehicular access would be required in design*
Utility Connections	5	*Minimal re-routing required*	5	*Minimal re-routing required*	4	*WICC site may require larger LV substation*	5	*Minimal re-routing required*
Suitability for Gas Boiler	5	*Gas supply, flue and vented space available*	5	*Gas supply, flue and vented space available*	3	*New gas supply to WICC MSCP & flue required*	3	*New supplies & flue required*
Suitability for CHP	5	*Gas supply, flue and double height space available*	5	*Gas supply, flue and double height space available*	3	*New gas supply to WICC MSCP & flue required*	3	*New supplies & flue required*
Suitability for Ammonia Heat Pump	5	*Can be located in purpose-built space*	3	*Would require new ventilation route to roof level*	5	*Can be located in purpose-built space*	5	*Can be located in purpose-built space*
Implications for Current & Planned Use	5	*Spaces available*	3	*Would require removal of existing services*	5	*Spaces available*	2	*Space would need to be retained by L.A.*
Suitability for Flueing	4	*New flue required at MSCP. Town Hall OK.*	5	*Existing chimney can be re-used*	3	*New flue required.*	3	*New flue required.*
Visual Impact	4	*Space within MSCP would be visible*	5	*Hidden from public view*	4	*Space within MSCP would be visible*	4	*TBC. Could be hidden from public view*
Environmental Impact	5	*No other issues identified*	3	*Adaptation of building structure may be required*	5	*No other issues identified*	4	*Allowance required in Union Place design*
Heat Network Implications	4	*Split site - increased complexity*	5	*Single site results in simple arrangement*	4	*Split site - increased complexity*	2	*200m from Civic Quarter Site*
Third Party Issues	4	*WICC & DEN delivery timeline in sync*	5	*None, local authority owned site*	4	*WICC & DEN delivery timeline in sync*	2	*Synchronisation between projects required*
Expansion Potential	3	*WICC MSCP site could have additional story(s)*	2	*Restricted double-height space available*	3	*WICC MSCP site could have additional story(s)*	5	*Expandability could be designed for*
Deliverability	4	*Adaptation of town hall plant room required*	3	*Adaptation of town hall basement required*	5	*Can be purpose built*	5	*Can be purpose built*
Total Score (%)	**85%**		**76%**		**78%**		**74%**	
Rank	1		3		2		4	

Table 3-1: Qualitative assessment of the different Energy Centre location options.

The qualitative assessment indicates that Option 1, with plant being located within the new MSCP (being delivered as part of the WICC development) and within the existing Town Hall plant room, as being the most suitable solution for locating DEN plant. This is primarily based on:

- both sites being within the Civic Quarter site and currently available for use;
- there is suitable provision of ventilation, flueing, utility connections and personnel access across both sites for a wide array of technological options;
- the larger area (in the car park) can be designed specifically for the purpose of housing DEN plant;
- minimal power and gas network extensions are required to serve both sites; and
- provision for vehicular access to both sites appears to be feasible.

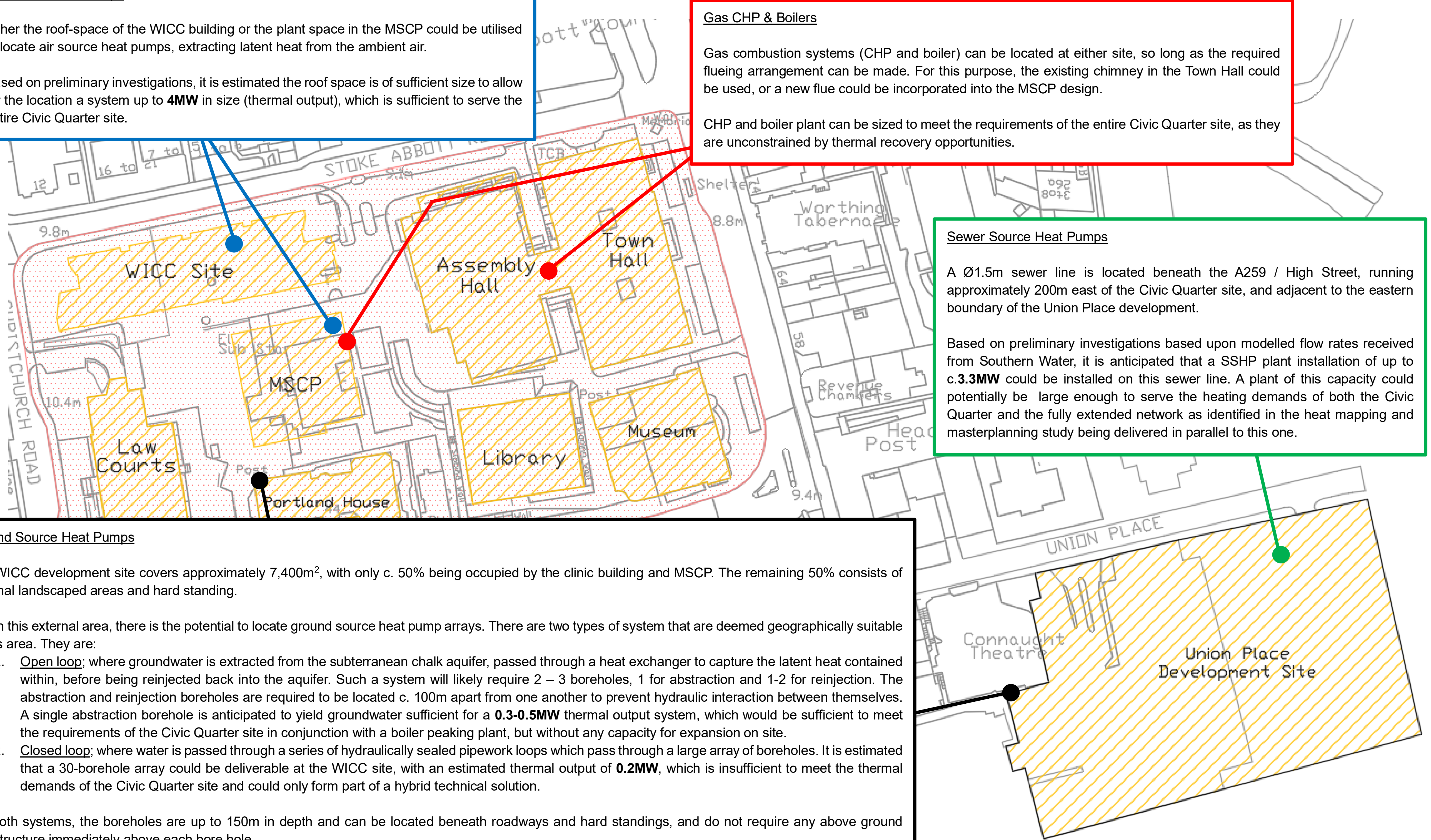
The majority of the modelling and designs contained within this report shall be based upon this solution, with two exceptions:

- any technical scenario that investigates the use of ASHPs shall assume EC Options 3, as the only area on site that this plant can be located is the roof-space of the WICC buildings; and
- any technical scenario that investigates Sewer Source Heat Pumps shall assume Option 4, as the only point at which the sewer can be intercepted is adjacent to the Union Place development site.

It should be noted that if the Union Place development were to be included as part of the network from the first day of operation, the above analysis would become more favourable to the siting of the EC at the Union Place site (Option 4).

4. Suitable Generational Technologies

The following generation plant solutions have been identified as being suitable to meet the energy demands of the Civic Quarter site. For details on this assessment, including which technologies were identified as being unsuitable, refer to Appendix F. The environmental and economic opportunity represented by each technology shall be considered within the modelling portion of this study, which is detailed in Section 7.



Air Source Heat Pumps

Either the roof-space of the WICC building or the plant space in the MSCP could be utilised to locate air source heat pumps, extracting latent heat from the ambient air.

Based on preliminary investigations, it is estimated the roof space is of sufficient size to allow for the location a system up to **4MW** in size (thermal output), which is sufficient to serve the entire Civic Quarter site.

Gas CHP & Boilers

Gas combustion systems (CHP and boiler) can be located at either site, so long as the required flueing arrangement can be made. For this purpose, the existing chimney in the Town Hall could be used, or a new flue could be incorporated into the MSCP design.

CHP and boiler plant can be sized to meet the requirements of the entire Civic Quarter site, as they are unconstrained by thermal recovery opportunities.

Sewer Source Heat Pumps

A Ø1.5m sewer line is located beneath the A259 / High Street, running approximately 200m east of the Civic Quarter site, and adjacent to the eastern boundary of the Union Place development.

Based on preliminary investigations based upon modelled flow rates received from Southern Water, it is anticipated that a SSHP plant installation of up to c.**3.3MW** could be installed on this sewer line. A plant of this capacity could potentially be large enough to serve the heating demands of both the Civic Quarter and the fully extended network as identified in the heat mapping and masterplanning study being delivered in parallel to this one.

Ground Source Heat Pumps

The WICC development site covers approximately 7,400m^2, with only c. 50% being occupied by the clinic building and MSCP. The remaining 50% consists of external landscaped areas and hard standing.

Within this external area, there is the potential to locate ground source heat pump arrays. There are two types of system that are deemed geographically suitable to this area. They are:

1. Open loop; where groundwater is extracted from the subterranean chalk aquifer, passed through a heat exchanger to capture the latent heat contained within, before being reinjected back into the aquifer. Such a system will likely require 2 – 3 boreholes, 1 for abstraction and 1-2 for reinjection. The abstraction and reinjection boreholes are required to be located c. 100m apart from one another to prevent hydraulic interaction between themselves. A single abstraction borehole is anticipated to yield groundwater sufficient for a **0.3-0.5MW** thermal output system, which would be sufficient to meet the requirements of the Civic Quarter site in conjunction with a boiler peaking plant, but without any capacity for expansion on site.
2. Closed loop; where water is passed through a series of hydraulically sealed pipework loops which pass through a large array of boreholes. It is estimated that a 30-borehole array could be deliverable at the WICC site, with an estimated thermal output of **0.2MW**, which is insufficient to meet the thermal demands of the Civic Quarter site and could only form part of a hybrid technical solution.

For both systems, the boreholes are up to 150m in depth and can be located beneath roadways and hard standings, and do not require any above ground infrastructure immediately above each bore hole.

Either system could be implemented within the existing WICC planning application without the need for additional planning permissions. However, there would be more licensing and other permissions required for the open loop option.

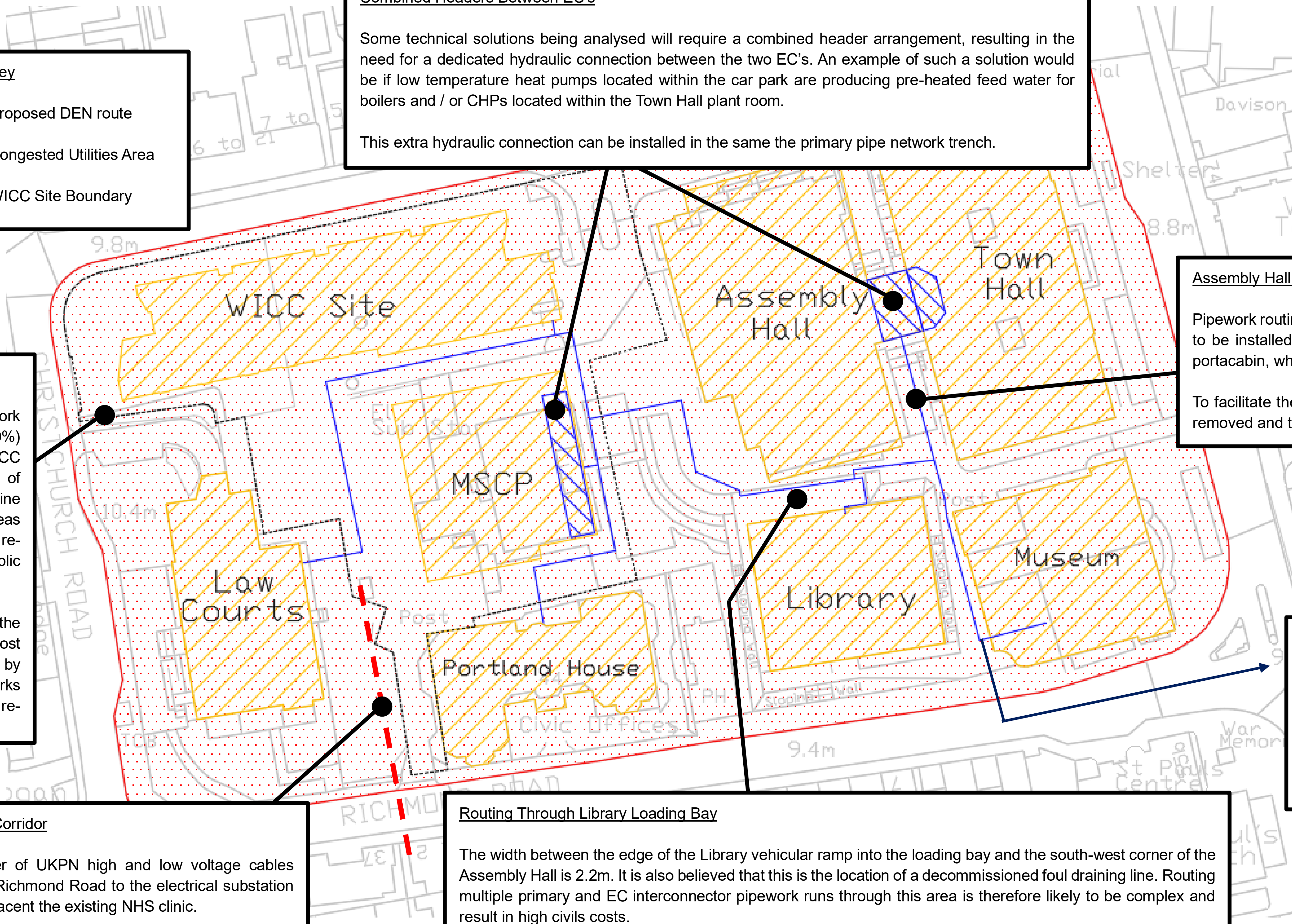
The Union Place development site could be utilised to locate additional borehole(s) as required, although this has not been considered in the analysis within this report.

5. Energy Distribution Strategy

The following delivery network route plan / concept design has been developed based upon the locations of the heating plant rooms within each building and the existing buried utility data (as determined by the buried utilities information provided by the different network operators obtained by the WICC development team). Notes have been included detailing non-typical aspects of the design. The route shown below shall primarily contain district heating pipework, however, depending on the technical solution being investigated, it can also include district cooling pipework and / or a power network (with any generated power being distributed via a connection located within the Town Hall plant room to the existing private wire network which serves the Town Hall, Assembly Hall and Law Court).

For additional details, including existing utility and constraint maps, refer to Appendix H.

5.1 Civic Quarter Route Plan



Drawing Key

- Proposed DEN route
- Congested Utilities Area
- WICC Site Boundary

Combined Headers Between EC's

Some technical solutions being analysed will require a combined header arrangement, resulting in the need for a dedicated hydraulic connection between the two EC's. An example of such a solution would be if low temperature heat pumps located within the car park are producing pre-heated feed water for boilers and / or CHPs located within the Town Hall plant room.

This extra hydraulic connection can be installed in the same the primary pipe network trench.

Assembly Hall Portacabin

Pipework routing in and out of the Town Hall plant room will need to be installed underneath the existing Assembly Hall storage portacabin, which is located within the courtyard space.

To facilitate the installation of pipework, this portacabin can be removed and then reinstated once works are complete.

WICC Site

A large portion of the total network utilities trench length (178m / 50%) is being routed through the WICC development site, the extent of which is shown by the black outline within this map. The external areas within the site are being re-developed to provide a public landscape.

By synchronising the delivery of the WICC and DEN projects, cost efficiencies can be gained by undertaking ground and civils works at the same time prior to re-surfacing.

Potential Union Place Connection

To connect to the Union Place development, either for the purposes of locating a sewer source heat pump or the Energy Centre offsite or connecting the site to the DEN, the shortest potential pipework route (180m) is down Chapel Road and across Union Place.

Congested Utilities Corridor

There are a number of UKPN high and low voltage cables running North from Richmond Road to the electrical substation currently located adjacent the existing NHS clinic.

The pipework has been routed to the north of this electrical power cable 'corridor' to mitigate technical and cost risks.

Routing Through Library Loading Bay

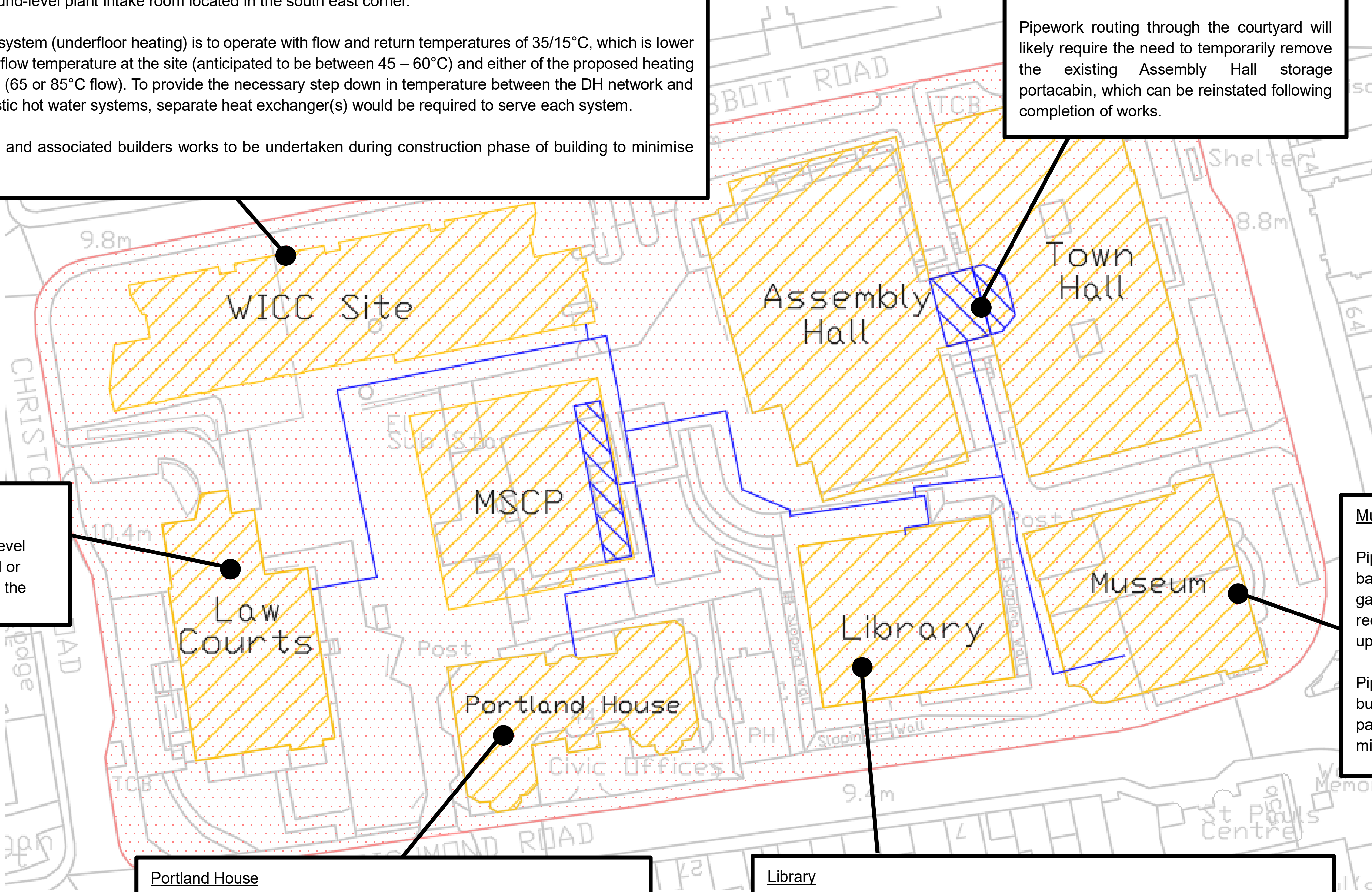
The width between the edge of the Library vehicular ramp into the loading bay and the south-west corner of the Assembly Hall is 2.2m. It is also believed that this is the location of a decommissioned foul draining line. Routing multiple primary and EC interconnector pipework runs through this area is therefore likely to be complex and result in high civils costs.

It is therefore proposed to route all services into the Library loading bay at high level, running along the length of the bay at high level and then back into a buried trench to reach the Town Hall and Museum plant rooms.

An illustration of this proposal in shown in Appendix H.

6. Building Connections and Adaptation Works

6.1 Building Connection Strategies



Integrated Care Centre

Pipework access into the ground-level plant intake room located in the south east corner.

The proposed space heating system (underfloor heating) is to operate with flow and return temperatures of 35/15°C, which is lower than both domestic hot water flow temperature at the site (anticipated to be between 45 – 60°C) and either of the proposed heating network temperature regimes (65 or 85°C flow). To provide the necessary step down in temperature between the DH network and the space heating and domestic hot water systems, separate heat exchanger(s) would be required to serve each system.

Pipework installation, ducting and associated builders works to be undertaken during construction phase of building to minimise cost and disruption to works.

Town Hall & Assembly Hall

Pipework access into the basement level plant room via external wall.

Pipework routing through the courtyard will likely require the need to temporarily remove the existing Assembly Hall storage portacabin, which can be reinstated following completion of works.

Law Courts

Pipework access into the basement level plant room via either the external wall or underground car park external wall in the north eastern corner of the facility.

Museum

Pipework access into the Museum basement plant room via the external garden area, proposed to be redeveloped into a café in the upcoming refurbishment project.

Pipework installation and associated builders works to be undertaken in parallel as refurbishment project to minimise cost and disruption.

Portland House

Pipework access into the Portland House roof-space plant room via a largely empty mechanical riser situated adjacent to the lift shaft on the north side of the building.

At the time of survey (June 2020), the riser was largely unused and blocked off, with only minor waste services present, and is assumed to be of suitable size in which to locate the required pipework.

Library

Pipework access into the Library basement plant room through the loading bay external wall. The pipework would be buried in a typical trench up the wall of the loading bay, at which point it would penetrate through the wall at ground level and become mounted at high level within the bay, routing around the external wall and into the plant room.

An illustration of this proposed solution is included in Appendix H.

6.2 Typical Thermal Substations Design

To facilitate the transfer of heat from the primary network to the connected buildings, the existing thermal generation plant is to be replaced with Plate Heat Exchanger(s) (PHExs). Typically, in district energy schemes, 2no. PHExs are connected in a duty assist arrangement, with each plate sized at 65% of the peak energy demand of the building. This arrangement ensures a resilient scope for supply in the event of one plate failing.

Each building connection features commissioning sets, differential pressure control, 2-port valves, heat meters and other valving, and has a dedicated controls outstation with power. A typical substation design drawing has been included in Appendix H.

6.3 Building Heat System Temperatures

In Chapter 4, heat pump-based solutions were identified as being a suitable technology to generate the thermal requirements of the site – which is currently the need to deliver hot water at c. 80°C to all existing sites.

The majority of the current single-stage heat pumps available on the market are typically limited to an output temperature of circa 65°C, although higher output temperatures are achievable - either through the use of:

- systems that consist of multiple heat pumps which are configured in series with one another (known as multiple-stage heat pumps), resulting in reduced overall system efficiencies and the need for double the plant space; or
- utilising alternative refrigerants within the heat pumps, such as ammonia (a technical solution that results in the need for additional plant space as dedicated ammonia storage areas are required as well as risk mitigation measures).

As both of these alternative solutions result in higher capital and maintenance costs, it would be preferable to enable the use of single-stage lower temperature heat pump solutions if possible. To facilitate this, the flow and return temperatures of the buildings need to be re-configured to be able to operate with a flow temperature of 65°C or lower. To achieve this, adaptations need to be made to the currently in-situ central heating systems within the buildings within the Civic Quarter site to ensure that the required internal temperatures can still be reached. The table below details the adaptations identified by AECOM and how they can be implemented:

Building	Adaptations required to allow for lower flow and return temperatures	Estimated level of disruption of adaptation works	Estimated additional capital cost (for details refer to Appendix D)
Town Hall	• Reduction in air permeation rates with secondary glazing • Rebalancing of heating circuits to allow for lower flow and return temperatures • Reprogram BMS to allow for longer start up times	Medium Secondary glazing works being undertaken regardless of district energy project.	Up to £111,500
Assembly Hall	• Reduction in air permeation rates with improved glazing • Rebalancing of heating circuits to allow for lower flow and return temperatures	Low	
Portland House	• Reduction in air permeation rates by refurbishing windows and sealing draughts. • Potential need to replace existing central heating emitter systems to improve functionality • Rebalancing of heating circuits to allow for lower flow and return temperatures • Reprogram BMS to allow for longer start up times	Medium Triple glazing replacement project being undertaken regardless of district energy project.	Up to £59,500
Museum and Art Gallery	• Consolidation of all heating systems into single centralised system • Specification of adapted centralised system to be tailored to DEN	Low Adaptation can be ensured through mechanical plant specifications of upcoming refurbishment project	Up to £63,000
Library	• Replacement of AHU heating and / or cooling coils which are not suitably sized for lower temperatures • Rebalancing of heating circuits to allow for lower flow and return temperatures • Reprogram BMS to allow for longer start up times	Medium Upcoming refurbishment project is likely to take place prior to DEN project	Up to £86,500
Law Courts	• Rebalancing of heating circuits to allow for lower flow and return temperatures • Reprogram BMS to allow for longer start up times • Extra works as required to be confirmed following a site survey	Low – Medium Site survey required to identify scope of works	Up to £63,000 (based on assumptions listed in Appendix B)
WICC Site	• None required, as current mechanical specification ultra-low temperature under floor heating (35°C flow)	None	None
Union Place Site	• Ensure that Section 106 planning requirements dictate that designs must cater for lower flow and return temperatures within the buildings.	Low	None, mechanical build specification can be tailored to meet DH requirements

Table 6-1: Works required to adapt or ensure secondary side space heating systems operate with lower flow and return temperatures

As part of this study, technical memorandums have been produced by AECOM and circulated to the relevant stakeholders; copies of these reports are contained within Appendix D.

To investigate the potential benefit of lowering the building system temperatures, a sensitivity analysis within the techno-economic modelling shall be conducted once a preferred solution has been identified. This shall additionally take into account the additional estimated capital costs (with a total allowance of £500,000 included to cover all buildings), reduced operational costs and carbon emissions associated with the implementation of works highlighted in Table 6-1, and will identify the level of potential benefit to the system.

7. Optioneering Modelling Study

This section describes the different scenarios modelled as part of the optioneering assessment and details the key outputs from the Techno-Economic Model (TEM). The outcome of this assessment will be used to identify the optimal heat generation plant to take forward as a preferred solution. For full details of the inputs and assessment methodology, refer to Appendix I.

7.1 Business as Usual Scenarios

To assess the viability of any proposed network, each solution must be compared against a 'Business as Usual' (BaU) scenario, of which three different viewpoints have been taken (as presented in Section 2.3):

- **BaU 1; Low Tariff Case / Do Northing:** At present, all of the buildings identified as potential customers to the network generate their heating from gas boilers and their cooling via electrically fuelled chiller plant.
- **BaU 2; Medium Tariff Case / 'Pay to Be Dirty':** At present, the UK government produces a series of cost metrics to estimate the social impact cost for generating CO_2 emissions and Air Quality Damage costs associated with consuming fuel sources. The cost impact of both of these items shall be incorporated into the 'Low Tariff Case'
- **BaU 3; High Tariff Case / 'Pay to be Clean':** To facilitate a transition into zero carbon operation without a DEN being developed, the existing gas boiler plants in each building would need to be replaced with an equivalent low carbon operation, with Air Source Heat Pumps being the most technically viable solution for individual buildings on site. The estimated capital costs to undertake this work are included in Appendix I.

The heat tariffs used within the TEM will be set to match all three BaU scenarios as part of the optioneering modelling detailed within this chapter. Use of the higher tariff cases will increase the revenue collected by the scheme, which can facilitate the installation and use of larger LZC plant resulting in higher levels of CO_2 reduction).

7.2 Base Scenarios

Based on four primary heating plant solutions, a total of eleven potential networks solutions have been developed in accordance with the identified energy demand requirements (Section 2.2) and energy generation opportunities (Section 4) discussed in this report. All proposed systems are heat-pump led to facilitate the largest possible carbon benefit, in accordance with A&WC's carbon neutral plan.

Primary Heat Generation Plant	*With backup boilers*	*With CHP and backup boilers*	*No backup plant*
OL - GSHP	*Scenario 1a*	*Scenario 1b*	*n/a*[8]
CL – GSHP and ASHP[9]	*Scenario 2a*	*Scenario 2b*	*Scenario 2c*
SSHP	*Scenario 3a*	*Scenario 3b*	*Scenario 3c*
ASHP	*Scenario 4a*	*Scenario 4b*	*Scenario 4c*

Table 7-1: Scheme scenarios to be analysed within the TEM

Every potential solution has been modelled within AECOM's TEM to ascertain the environmental and economic benefits of each. For each scenario under each different BaU, the plant sizing and scheme design has been set with the target that the project maximises carbon savings whilst achieving a positive un-funded project IRR which can be raised to 6%[10] with the use of grant funding within the bounds of state aid limitations[11] .

7.2.1 Base Scenario Results

			Network Details									Results													
			EC Plant						EC Location			BaU #1: Gas Boiler Tariff				BaU #2: Gas Boiler & Social Value Tariff				BaU #3: ASHP Tariff				
Scenario ID#	Scenario Description		OL-GSHP	CL-GSHP	SSHP	ASHP	Gas CHP	Gas Boiler	MSCP & Town Hall	MSCP & WICC Roof	Union Place	Total CAPEX (£m)	40-Year Project IRR	40-Year C02 Reduction vs Gas Boilers (tonnes / % of total)	Eligible for HNIP Funding to 6% IRR	Total CAPEX (£m)	40-Year Project IRR	40-Year C02 Reduction vs Gas Boilers (tonnes / % of total)	Eligible for HNIP Funding to 6% IRR	Total CAPEX (£m)	40-Year Project IRR	40-Year C02 Reduction vs Gas Boilers (tonnes / % of total)	40-Year C02 Reduction vs ASHPs (tonnes / % of total)	Eligible for HNIP Funding to 6% IRR
BaU	Building level ASHP installations					●						n/a				n/a				£1.3	n/a	14,100 / 87%	n/a	
1a	OL - GSHP	with boiler back-up	●					●	●			£1.4	-	11800 / 73%	✗	£1.4	1.53%	11800 / 73%	✓	£1.4	12.21%	11800 / 73%	*negative*	> 6%
1b	OL - GSHP	with CHP & boiler back-up	●				●	●	●			£2.0	1.44%	3500 / 22%	✓	£2.2	4.12%	5500 / 34%	✓	£2.2	10.69%	5500 / 34%	*negative*	> 6%
2a	CL - GSHP & ASHP	with boiler back-up		●				●	●			£1.4	-12.62%	7900 / 49%	✗	£1.4	1.59%	7900 / 49%	✓	£1.9	6.80%	13800 / 86%	0 / 1%	> 6%
2b	CL - GSHP & ASHP	with CHP & boiler back-up		●			●	●	●			£2.0	1.42%	2700 / 16%	✓	£2.4	2.49%	5600 / 35%	✓	£2.4	8.66%	5600 / 35%	*negative*	> 6%
2c	CL - GSHP & ASHP	heat pump only		●					●			£2.3	-	13800 / 86%	✗	£2.3	-6.59%	13800 / 86%	✗	£2.3	4.55%	13800 / 86%	0 / 1%	✓
3a	SSHP	with boiler back-up			●			●			●	£3.1	-	14000 / 87%	✗	£3.1	-11.51%	14000 / 87%	✗	£3.1	1.86%	14000 / 87%	300 / 11%	✓
3b	SSHP	with CHP & boiler back-up			●		●	●			●	£2.6	-0.88%	4100 / 26%	✗	£2.6	2.69%	4100 / 26%	✓	£2.6	8.45%	4100 / 26%	*negative*	> 6%
3c	SSHP	heat pump only			●						●	£3.2	-	14100 / 88%	✗	£3.2	-	14100 / 88%	✓	£3.2	1.29%	14100 / 88%	400 / 16%	✓
4a	ASHP	with boiler back-up				●		●		●		£1.2	-	7100 / 44%	✗	£1.2	1.57%	7100 / 44%	✓	£1.2	13.92%	7100 / 44%	*negative*	> 6%
4b	ASHP	with CHP & boiler back-up				●	●	●		●		£1.9	1.42%	1200 / 7%	✓	£2.1	3.54%	5000 / 31%	✓	£2.1	10.50%	5000 / 31%	*negative*	> 6%
4c	ASHP	heat pump only				●				●		£1.4	-	13500 / 84%	✗	£1.4	-5.69%	13500 / 84%	✗	£1.4	9.14%	13500 / 84%	*negative*	> 6%

Table 7-2: Headline modelling results for the 11 scenarios when modelled with the 3 BaU tariff scenarios. Note that plant sizes for each solution vary for each BaU (to estimate maximum levels of CO_2 savings available under each tariff scenario)

[8] The use of open loop GSHPs without any backup technology is not a viable scenario as the system would not be self-resilient as the abstraction of ground water is subject to curtailment by the EA.

[9] Spatial limitations within the WICC development site restrict the maximum thermal output of a CL – GSHP to circa 200kW$_{th}$, so additional LZC thermal capacity is provided in this system by ASHPs.

[10] The target IRR value of 6% has been chosen in accordance with the typical internal hurdle rate for investment used by local authorities for energy projects.

[11] State aid limitations have been assumed at a maximum gross grant equivalent contribution of 45% of the total scheme CapEx.

The base case results show that:

- **Carbon savings:** The sewer source heat pump offers the highest level of carbon savings, as the source temperatures are higher than the other heat sources (aquifer, ground or air), especially during the winter heating season. The aquifer and ground source heat pumps offer slightly lower carbon savings, followed by air source. Any option that includes CHP offers significantly lower carbon savings as the gas grid is not anticipated to decarbonise at the same rate as the power grid.
- **BaU 1; Low Tariff Case:** Using a heat tariff structure equal to the operation of the existing gas boiler plant, only three possible schemes result in a positive IRR – all are hybrid systems using either open-loop or closed loop GSHP or ASHP combined with gas-CHP and backup gas-boilers, achieving carbon savings of between 7 and 22%. These are the only economically viable solutions against this low heat tariff scenario due to the lower overall operational costs driven by the revenues obtained from generating power from CHP for use by both the heat pump and for sale to the existing private wire network;
- **BaU 2; Medium Tariff Case:** Using a heat tariff structure equal to the operation of the existing gas boiler plant with additional social value accounted for, eight of the eleven potential schemes result in a positive IRR, which with grant funding can achieve 6% project-IRR within state aid limitations.
- **BaU 3; High Tariff Case** Using a heat tariff structure equal to the costs of running air source heat pump plant in each building results in all schemes returning a positive IRR, with eight over the anticipated hurdle rate of 6% (and therefore not in need of gap funding). However, only four scenarios (all using either SSHP or CL-GSHP and ASHP hybrid solutions) represent a scheme which does not produce additional CO_2 emissions against a building-level ASHP conversion counterfactual – although all scenarios do achieve a significant reduction in CO_2 emissions when compared to gas boiler operation.

For each BaU, the schemes have been ranked in terms of their carbon savings, but only if a 6% funded project IRR is achievable:

	Gas Boilers BaU	Gas Boiler & Social Value BaU	ASHP BaU
Rank 1	OL-GSHP with CHP & boilers [1.44% IRR; 22% CO_2 reduction]	OL-GSHP with boilers [1.53% IRR; 73% CO_2 reduction]	SSHP only [1.29% IRR; 88% CO_2 reduction]
Rank 2	CL-GSHP & ASHP hybrid with CHP & boilers [1.42% IRR; 16% CO_2 reduction]	CL-GSHP & ASHP hybrid with boilers [1.59% IRR; 49% CO_2 reduction]	SSHP with boilers [1.86% IRR: 87% CO_2 reduction]
Rank 3	ASHP with CHP & boilers [1.42% IRR; 7% CO_2 reduction]	ASHP with boilers [3.54% IRR; 44% CO_2 reduction]	CL-GSHP & ASHP hybrid with boilers [6.8% IRR; 86% CO_2 reduction]

Table 7-3: Ranking, in terms of CO2 savings and economic return, of the base-case scenarios for each BaU scenario

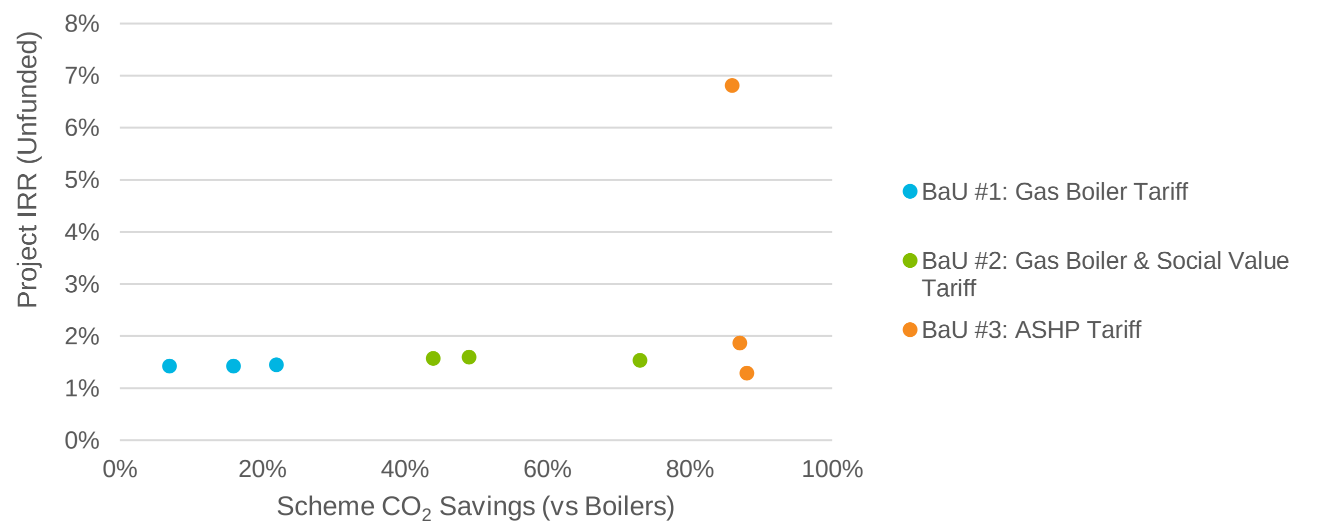


Figure 7-1: Plot of top-three ranked solutions for each BaU scenario showing CO_2 savings and unfunded IRRs

The analysis shows:

- That an open-loop GSHP led system is the top scoring solution for the low and medium case solutions, and the SSHP solution is the top scoring under the high tariff scenario;
- Without an increase in the heating tariff currently paid by the buildings, a CHP is required to offer a 6% project IRR, due to the reduction in fuel costs to operate the network; and
- There is a strong correlation indicating that the higher the heat tariff paid by the customers, the higher the level of carbon reduction can be achieved by the scheme. No or minimal gap funding would be required to meet the 6% hurdle rate should an ASHP based tariff be used, whereas more substantial gap funding is required should lower (gas boiler equivalent) tariffs be used.

7.3 Sensitivity Analysis

In addition to the base-case sensitivities investigated within the optioneering analysis, additional models have been run to investigate ways to optimise the base solutions. Each sensitivity has been tested in isolation to investigate its impact. The sensitivities investigated are:

1) The inclusion of the Union Place development in the core scheme;
2) The inclusion of all works required to reduce the operational temperatures of all buildings;
3) The inclusion of a cooling network, capturing the waste coolth generated through the operation of the heat pumps (refer to Appendix G for full details); and
4) The use of a private purchase agreement with a biogas generator to operate gas-CHP plant.

To simplify the level of information presented, only the results based on 'medium-case' heat tariffs are shown here.

The table below details the impact of each sensitivity scenario investigated:

Sensitivity	Effect on base scheme economic viability	Effect on base scheme CO_2 reduction	AECOM Recommendation
Inclusion of Union Place	Substantial Improvement	Improvement	Include in scheme
Lowering of building temperatures	Substantial Improvement	Improvement	Include in scheme
Inclusion of a cooling network	Minor Reduction	Improvement	Potential to develop system at a later date
Switching to green gas tariffs	Substantial Reduction	Improvement *only if CHP included in preferred option*	Exclude from scheme

Table 7-4: Outcome from sensitivity analysis

All the sensitivities scenarios analysed result in higher levels of CO_2 emissions reduction in comparison to the base scenarios. However, only the inclusion of the Union Place development and reduction in building internal heating system temperatures also offer an economic benefit. All sensitivities also increase the level of technical, economic and / or deliverability risks associated with the implementation of a DEN.

For full results and further details, refer to Appendix K.

7.4 Summary of Optioneering Study

Table 7-5 below highlights the key benefits and restrictions for the use of each of the identified potential LZC technical solutions considering the:

- Outcome from the optioneering TEM assessment; and
- The desktop feasibility assessments into the viability of each technology to serve the Civic Quarter site (the outputs of which have been discussed in Section 4). These assessments highlighted the technical risks and potential mitigation strategies for each solution.

LZC Solution	Key Benefits	Key Restrictions	Key Technical Risks	Key Risk Mitigation Strategies	Note on Mitigation Costs
OL-GSHP	- Highest scoring scheme in low and medium tariff cases	- Potential that the solution proves undeliverable - Additional off-site borehole(s) would be required to add the generational capacity required to extend the scheme	- Reinjection of groundwater into aquifer could cause water table to rise increasing risk of localised flooding - Above risk can be mitigated by rejection of water to sewer, if permitted by the Environment Agency (EA) and Southern Water (SW)	- Investigate potential to reject abstracted water to sewer system with EA and SW - Investigate potential to utilise abstracted water on site, i.e. grey water use (toilet flushing, dish washing etc.) - Drill pilot boreholes & run tests to ascertain viability of reinjecting water to aquifer	- No cost associated with EA pre-application consultation - Higher up-front costs associated with installing test boreholes (up to £200,000). Test boreholes can be converted for use in real scheme; however, there is a risk cost could be lost if system is found to be unworkable.
CL-GSHP	- Established technical solution	- Footprint of WICC development site is insufficient to allow for a CL-GSHP led scheme to meet demand of Civic Quarter network, therefore can only form part of a hybrid heat-pump system. - Additional off-site array(s) would be required to add the generational capacity required to extend the scheme	- Long term cooling of ground temperatures resulting from only operation of heating-only solution, resulting in lower efficiencies and system becoming inoperable due to freezing of groundwater.	- Include delivery of cooling demand from system - Capture waste heat (e.g. from server cooling systems in Town Hall, Library & Law Courts) and use to maintain ground temperatures.	- Inclusion of cooling network estimated to have small detrimental impact on project-IRR (from sensitivity analysis), but scheme still considered viable. - Additional capital costs associated with the capture of waste heat from server cooling systems. - Risk that all local server systems may be removed from sites due to the rise in cloud-based computing
SSHP	- Highest scoring scheme in high tariff case - Potential to expand system up to circa 3.3MW, enough to serve Worthing-wide DEN scheme (with capital costs per kW significantly reducing with capacity)	- High initial capital costs - Unproven technology in UK	- Estimated flow and temperature data is taken from SW computer models and does not represent actual operation - System is unproven in England - High capital costs	- Install monitoring equipment to capture flow and temperature data - Pilot projects are being developed in Scotland. - Operational projects in Europe & Canada	- Small cost associated with installing monitoring equipment (est. £4,000 - £8,000)
ASHP	- Lowest capital cost per kW of any heat pump system - Potential to easily expand system as network expands, although additional off-site locations may be required	- Low generational efficiencies result in higher running costs	- Large scale of plant and GIA availability could result in local lowering of air temp and low efficiencies	- Design of either MSCP plant space or WICC roof-space to take into account ASHP installation from an early stage	- n/a
CHP	- Additional revenue stream from generated power, used either within EC and / or existing Private Wire network, can result in heat sale tariffs in line with current gas boiler operation	- CHP is fuelled by natural gas, which is not anticipated to decarbonise in the short term at the same rate as the power grid, resulting in significantly higher CO2 emissions that heat-pump only solutions	- Scheme CO_2 emissions increased (although still offer a saving versus the present-day use of gas boilers) - Air quality impact	- Significant off-site CO_2 offsetting required to achieve WBC carbon neutral targets - Low NO_x engines are commercially available & flue gas scrubbing technology available can also reduce impact.	- Mitigation strategies increase capital and operation costs of scheme

Table 7-5: Key technical risks of different technical solutions and potential mitigation strategies

7.5 Potential Extension of Network

Alongside this feasibility study, an additional Heat Mapping & Masterplanning study has been conducted, which has investigated the potential for the network to extend beyond the Civic Quarter site. The headline findings from this study are as follows:

7.5.1 Thermal Load

Substantial additional thermal load suitable for connection onto a DEN was located within Worthing Town Centre, suggesting that any heat network created to serve the Civic Quarter site has the potential to:

- Phase 1; expand to additional sites in the adjacency of the Civic Quarter and Union Place sites;
- Phase 2; branch out eastward to the hospital and Davison and Splashpoint leisure centres; and
- Phase 3; branch out southward towards the retail centre of the town.

These are illustrated in the heat map below:

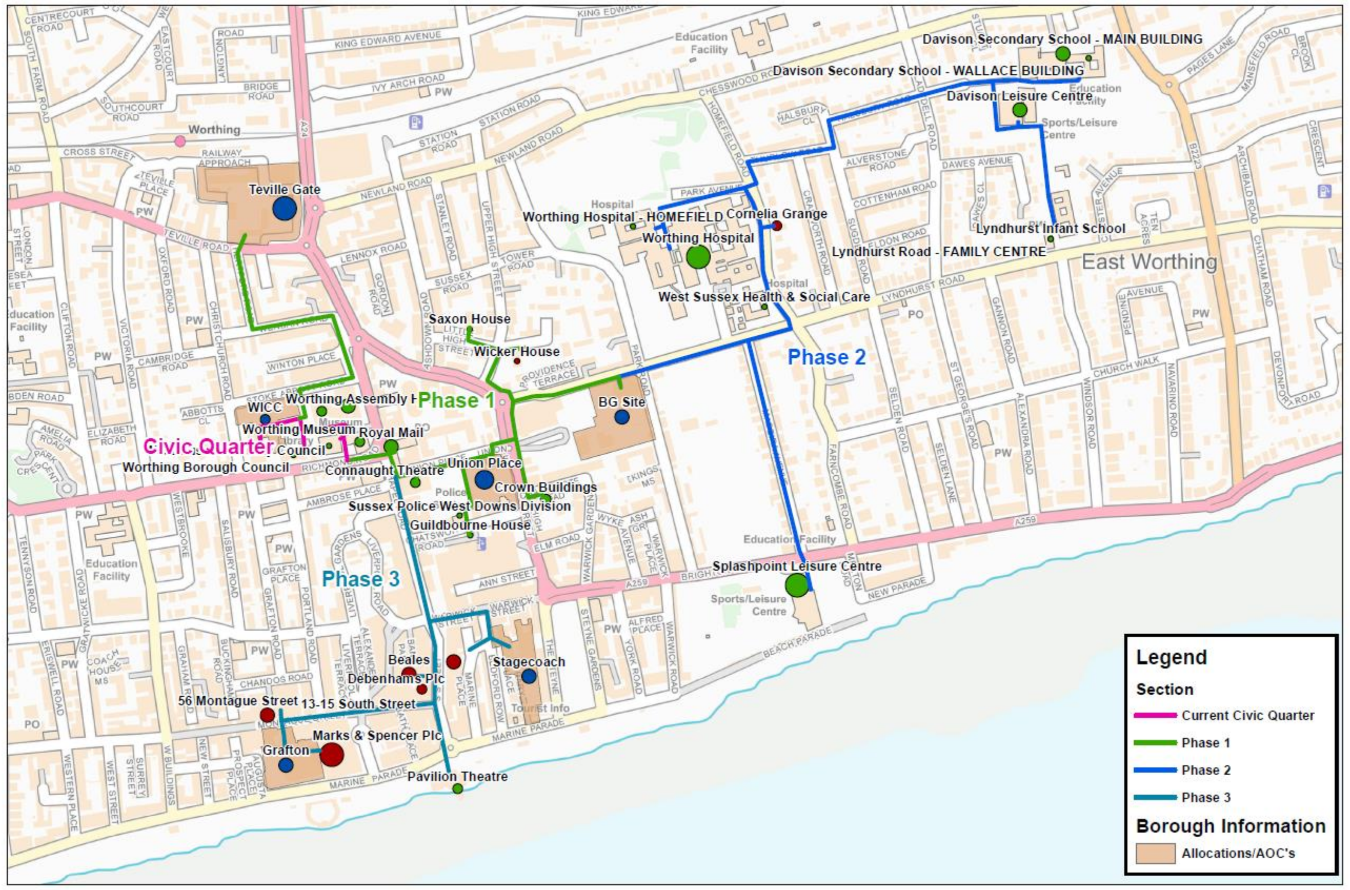


Figure 7-2: Additional thermal loads within Worthing Town Centre, identified as part of the Heat Mapping study

The completion of any DEN solution serving Worthing Town Centre is estimated to take place over as per the following programme:

Phase	Completion Date	Summary
Civic Quarter and Phase 1	2022 / 2023	Core network developed serving the Civic Quarter as well as the Union Place, British Gas (BG) and Terville Gate development sites and other existing buildings in the adjacency.
Phase 2 and 3	2025	Network extends easterly (phase 2) and southerly (phase 3) to serve the wider Worthing area.

Table 7-6: Assumed phasing strategy for the purposes of modelling the extended DEN scheme

7.5.2 Additional LZC Energy Sources & Optioneering Assessment

The following LZC energy sources that could be incorporated into a Worthing Town Centre wide network were identified across the wider Worthing area.

LZC Energy Source	Location	Estimated limiting thermal output capacity
OL-GSHP	Additional borehole couplets could be located at other two new development sites – 'Grafton', and 'Stagecoach' and Multiple couplet arrays within in Homefield Park and Davison Leisure centre playing fields.	Circa 350kW per development site & Up to circa 2MW in each park or playing field site
CL-GSHP	Large borehole arrays could be located in green field spaces in Homefield Park and / or Davison Leisure centre playing fields.	Circa 6MW in each park or playing field site
SSHP	The sewer identified as being suitable to serve the Civic Quarter site contains sufficient flow to serve 75% of fully extended scheme demand	Circa 3MW
ASHP	Heat can be extracted from the ambient air at any location in Worthing	Unlimited
Marine source HP	Heat can be extracted from the sea water	Unlimited

Table 7-7: Additional LZC energy sources identified in the wider Worthing area

Following the optioneering assessment of multiple different system masterplans, the SSHP based solution was shown to be the optimal lead LZC technology for a larger network. This is primarily because the

- larger SSHP installation benefits significantly from economy of scale, as the civil engineering portion of the installation – the creation of a wet well to interface with the sewer – has roughly the same capital cost regardless of the scale of the heat pump plant; and
- the relatively high and seasonally stable flow temperatures throughout the year, resulting in a higher average annual efficiency than other systems that are more responsive to weather conditions.

The second highest scoring technology was the CL -GSHP.

7.5.3 Developed Scheme

The final developed solution is shown below, incorporating both of the top two scoring technologies to meet the entire demands of the network:

Parameter	Value
SSHP Details	3MW (maximum capacity) plant installed in Phase 1 (Civic Quarter / Union Place EC).
GSHP Details	Up to 3MW capacity array in an additional EC installed within the Davison Leisure Centre playing grounds in Phase 2.
Levelised Cost of Heat	9.20 p/kWh
Capital Cost	Up to £16.3 million
HNIP Grant to Provide 6% Project IRR	Up to £6.67 million
40-year CO_2 reduction against BaU 1	170,000 tonnes; 85% total reduction
40-year CO_2 reduction against BaU 2	5,400 tonnes; 15% total reduction

Table 7-8: Details of developed scheme

8. Developed Options

Based on initial engagement with WBC, it is anticipated that the council is receptive to the idea that, to facilitate a transition to net zero carbon operation, it is necessary for the current levels of spend on energy provision to increase. Therefore, the following top-ranking technical solutions for the two increased tariff cases shall be presented in more detail in this section, with a view to further optimisation to lower costs to customers and increase the CO_2 savings:

1) **Medium tariff case**: The top-ranking solution for this BaU base-scenario was identified as being the **Open Loop GSHP with backup boiler** option, *subject to confirmation that abstracted water can either be safely reinjected into the aquifer without resulting in flooding issues or rejected to the sewer network.*
2) **High tariff case**: The top-ranking solution for this BaU base-scenario was identified as being the **SSHP with backup boiler** option.

8.1 Developed Option 1 – Open Loop Ground Source Heat Pump

This developed solution differs from that presented in the optioneering analysis in Section 7 as per the following:

- The output of the OL-GSHP system is limited to 350kW, based on an anticipated yield of 5 litres/second groundwater (refer to Appendix F.1); and
- As identified through modelling sensitivity analysis, it was identified that by if additional provision in the DEN capital budget was allowed for to lower the flow and return temperatures within each building, then considerable operational benefit of an OL-GSHP could be achieved.

Although inclusion of Union Place was shown to have environmental and economic benefit, the limitations of the thermal output of the OL-GSHP system located in the Civic Quarter mean that the additional demand could not be served without additional borehole couplet(s). Union place has therefore been excluded from this developed option.

8.1.1 Developed Solution Details

Parameter	Value
Annual Heat Consumption	2,362 MWh
Peak Heat Demand	0.85 MW
Heat Pump Capacity	0.35 MW
Gas Boiler Capacity	1.1 MW
Heat Split – Heat Pump / Boiler	87% / 13%
Total Capital Cost	£1.9 Million
Levelised Cost of Heat	8.7 p/kWh
Estimated Commercial User Tariff – 2022[12]	9.21 p/kWh *DH tariff set equal to BaU tariff 2 –the operation of the existing gas boiler plant with additional social value accounted for*
Grant funding required for 6% IRR	£0.8 million / 43% of total CAPEX

Table 8-1: Key network parameters for the developed SSHP solution

	25-year Assessment	30-year Assessment	40-year Assessment
Project unfunded-IRR	-2.00%	0.08%	1.89%
Carbon savings, tonnes	7,492	9,060	12,197
Carbon savings *in comparison to gas boiler operation*	73.8%	74.5%	75.3%

Table 8-2: Key network economic and environmental performance factors

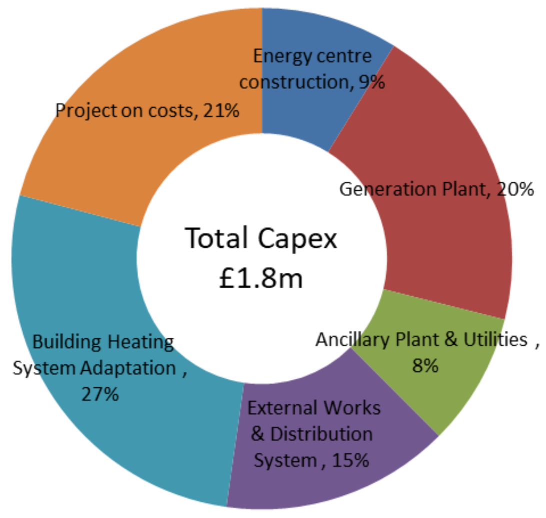


Figure 8-1: Breakdown of capital costs of developed OL-GSHP solution

8.1.2 Open Loop Ground Source Heat Pump – Borehole Locations

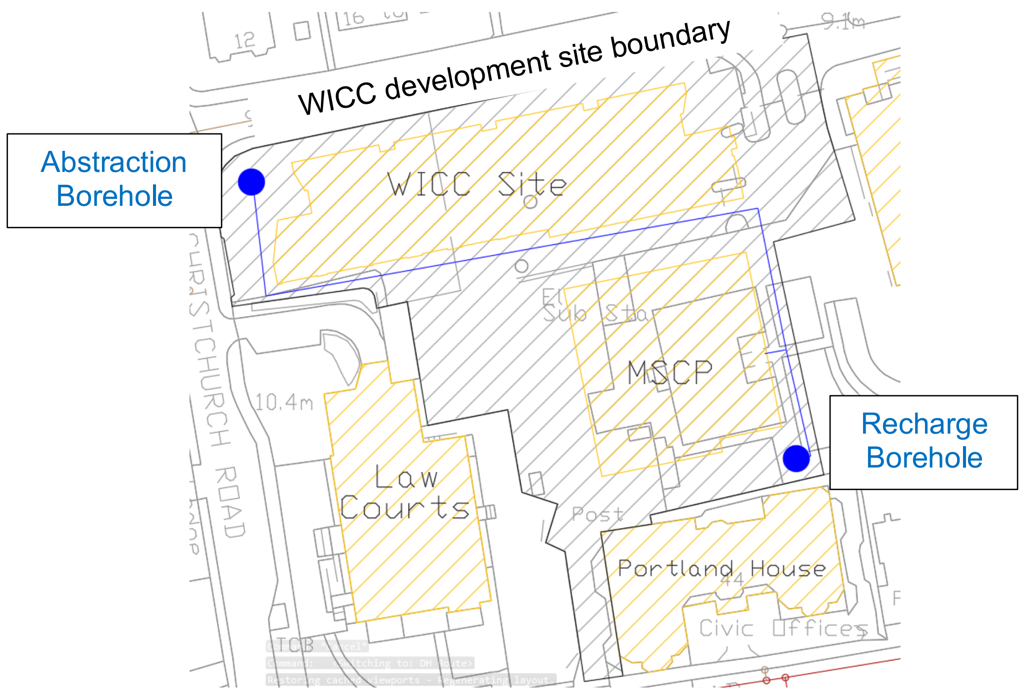


Figure 8-2: Concept design for abstraction and recharge borehole locations

[12] Note, a small degree of tariff escalation is modelled in line with the BEIS projected real price escalation of electricity sale tariffs.

8.2 Developed Option 2 – Sewer Source Heat Pump

This developed solution differs from that presented in the optioneering analysis in Section 7 as per the following:

- As per developed option 1, DEN capital budget has been allowed for to lower the flow and return temperatures within each building in this developed option;
- The potential to increase the thermal capacity of the SSHP to additionally serve the Union Place development is possible, therefore an increased HP size and additional building connections have also been included in this option; and
- The commercial heat tariff has been set by the model to determine the required revenue to achieve the lowest possible CO_2 reduction. Note – this new value is now 4% higher than the 'Pay to be dirty' tariff (BaU 2) but substantially lower than the 'Pay to be clean' tariff (BaU 3) used within the optioneering assessment in Section 7.

Note - as soft market testing (refer to Appendix F.3) has highlighted that a SSHP system becomes considerably better value for money as it increases in scale (due to the high civils costs associated with accessing the sewer), the inclusion of additional building connections within Worthing Town Centre could result in lower heat tariffs to all customers. It is recommended that the initial scope of the network be as large as possible should a SSHP system be pursued.

8.2.1 Developed Solution Details

Parameter	Value
Annual Heat Consumption	3,370 MWh
Peak Heat Demand	1.6MW
Heat Pump Capacity	1MW
Gas Boiler Capacity	2MW
Heat Split – Heat Pump / Boiler	100% / 0%
Total Capital Cost	£4.3 Million
Levelised Cost of Heat	11.3 p/kWh
Estimated Commercial User Tariff – 2022[13]	12.25 p/kWh *(a 33% increase over BaU tariff 2, equal to 9.21p/kWh)*
Estimated Residential User Tariff - 2022	10.68 p/kWh[14]
Grant funding required for 6% IRR	£1.27 million [15]

Table 8-3: Key network parameters for the developed SSHP solution

	25-year Assessment	30-year Assessment	40-year Assessment
Project unfunded-IRR	-2.75%	-0.33%	+1.64%
Carbon savings, tonnes	13,800	16,700	22,500
Carbon savings *in comparison to gas boiler operation*	88.9%	89.5%	90.5%

Table 8-4: Key network economic and environmental performance factors

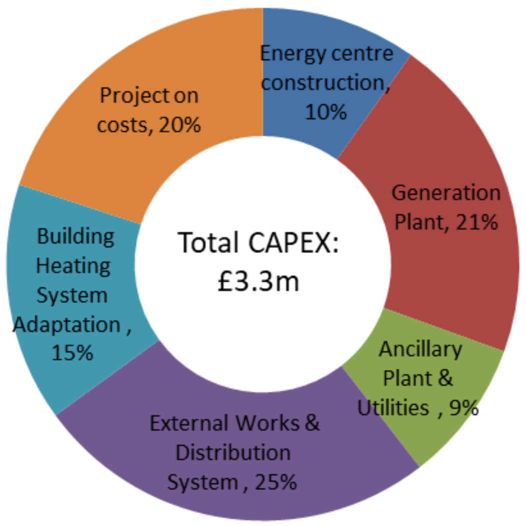


Figure 8-3: Breakdown of capital costs of developed SSHP solution

8.2.2 Sewer Connection Design

In this developed option, the primary energy centre locations have remained in the Civic Quarter despite the possibility to site all equipment within the Union Place development, as this alternative would increase programming risk associated with the need for the Union Place construction programme to be tailored to meet the heat on dates of the WICC development.

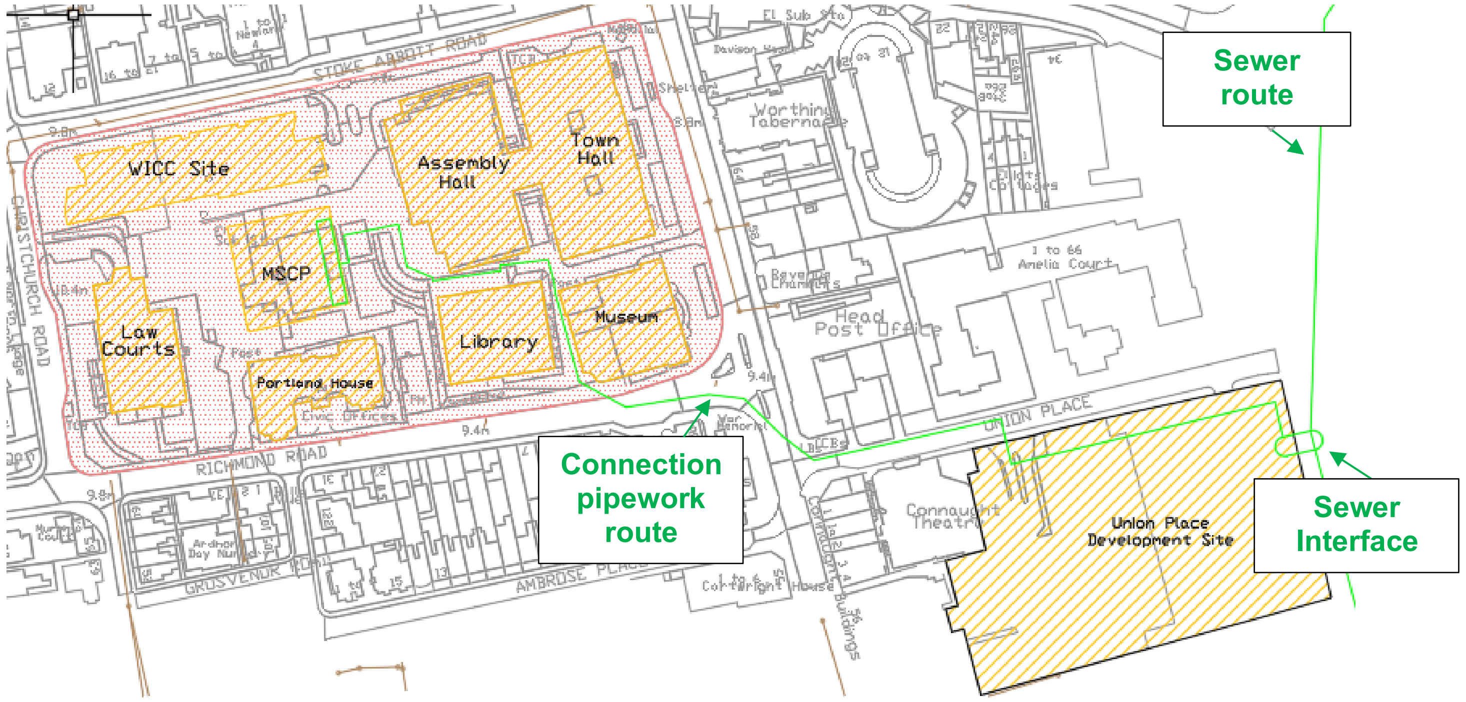


Figure 8-4: Concept design for ambient heat connection between the sewer interface in Union Place and the heat pump equipment in the WICC MSCP EC

[13] Note, a small degree of tariff escalation is modelled in line with the BEIS projected real price escalation of electricity sale tariffs. Refer
[14] Set to ensure Union Place residential tenants do not pay more than gas boiler generation, as based on the heat trust requirements.

[15] Determined by the anticipated state aid limit of 45% of the total capital cost applicable for HNIP funding, which excludes building internal heating system upgrade works.

8.3 Concept System Designs

The concept design for the EC's contained in this section are applicable to either the OL-GSHP or the SSHP solution. A full concept design drawing pack has been issued alongside this report (Appendix L).

8.3.1 Energy Centre - WICC Site

The below design has been generated based upon a vertical enlargement of the space allocated within the MSCP facility to allow for an additional mezzanine floor above the ground floor.

8.3.1.1 Ground Floor - Multi Story Car Park EC

The ground floor includes the primary generation plant (ammonia heat pumps and associated storage tank), as well as the ground-array manifolds, thermal store, expansion vessels and ammonia scrubber plant.

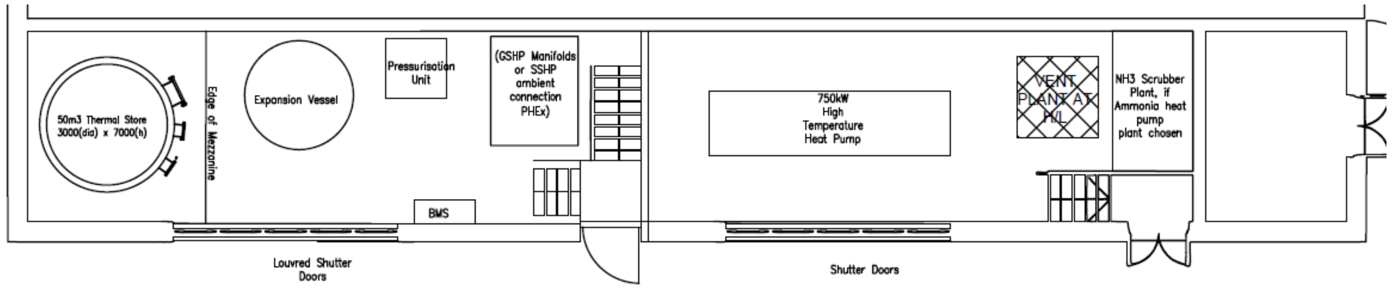


Figure 8-5: Concept design for the ground floor of the plant area within the MSCP.

8.3.1.2 Mezzanine Floor - Multi Story Car Park EC

The inclusion of a mezzanine floor in the MSCP plant room ensure that the required height clearance for the thermal stores, ammonia heat pumps and ammonia storage tanks are provided. It also allows for the location of some smaller ancillary plant items, including the primary heat (pump) set and water treatment plant items.

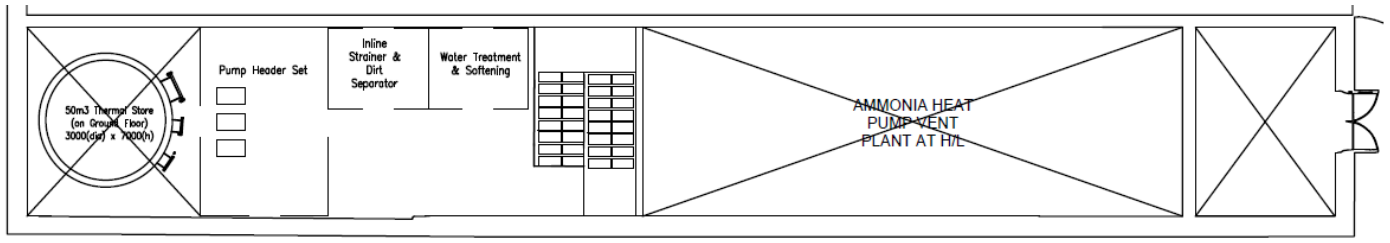


Figure 8-6: Concept design for the ground floor of the plant area within the MSCP.

8.3.1.3 Cost Implications to WICC Site

Benchmark costs associated with the creation of the substructure and superstructure have been included in the cost plan in the TEM, and as a result there will be no capital impact to the WICC development for creation of these areas.

The proposed design does not impinge on the number of car parking spaces within the MSCP, as it only utilises space that is already allocated for locating plant items (as per the WICC designs generated for outline planning application). As a result, no operational cost associated with lost car parking revenue has been included within the DEN cost plan.

8.3.2 Energy Centre - Town Hall Plant Room

The only plant items required to be situated within the Town Hall plant room are the backup gas boilers and associated shunt pumps. These can fit adequately with the existing boiler room, whilst also utilising the existing natural ventilation and chimney stack to exhaust to high level.

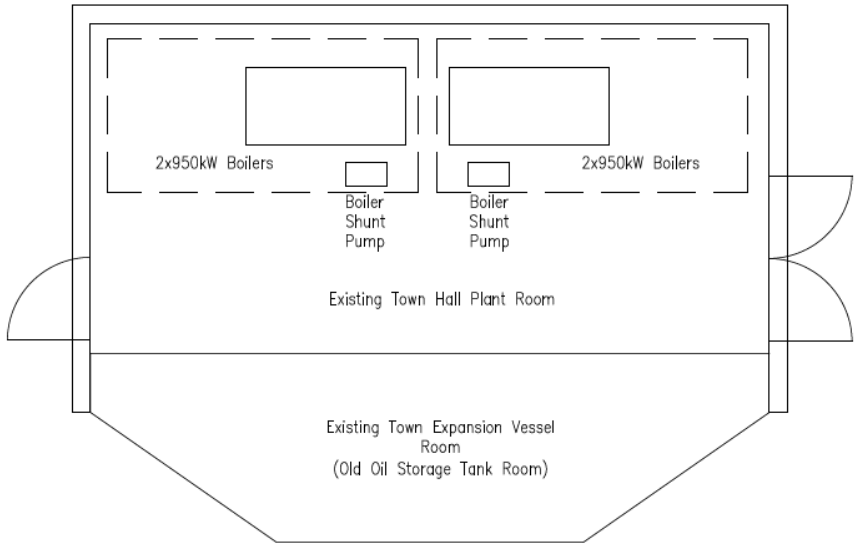


Figure 8-7: Concept design for the Town Hall plant room.

8.3.3 Futureproofing of Design to Enable Future Extension of Network

The potential of extension of the network discussed in Section 7.5 highlighted that, based on currently existing buildings and the Draft Worthing Plan, there is scope to extend the network in the easterly and southerly directions. To expand the LZC generational capacity to meet these additional demands, the following plant expansion methods are required for the two developed solutions:

- **OL-GSHP solution:** the Civic Quarter thermal demand is likely to fully utilise the plant, thus allowance for additional GSHP boreholes would be required should the scheme extend.
- **SSHP solution**: to allow for simple expansion of DEN scheme, the primary plant areas would be designed in a modular fashion allowing for additional plant items to be added as required, sharing the infrastructure that accesses and extracts the flow from the sewer.

The estimated maximum plant sizes that could be installed within the identified energy centres is estimated below:

Plant Item	Allowance in Concept Design serving Civic Quarter only	Estimated maximum potential plant size
OL-GSHP	350 kW	350 kW
SSHP	1MW	3.3MW

Table 8-5: Maximum potential oversizing of day 1 thermal generation plant

In the case of the SSHP solution, to be able to distribute this increased thermal power, provision for larger pipework from the EC's to the point from the network can be extended is also necessary. This has been illustrated in the figure below:

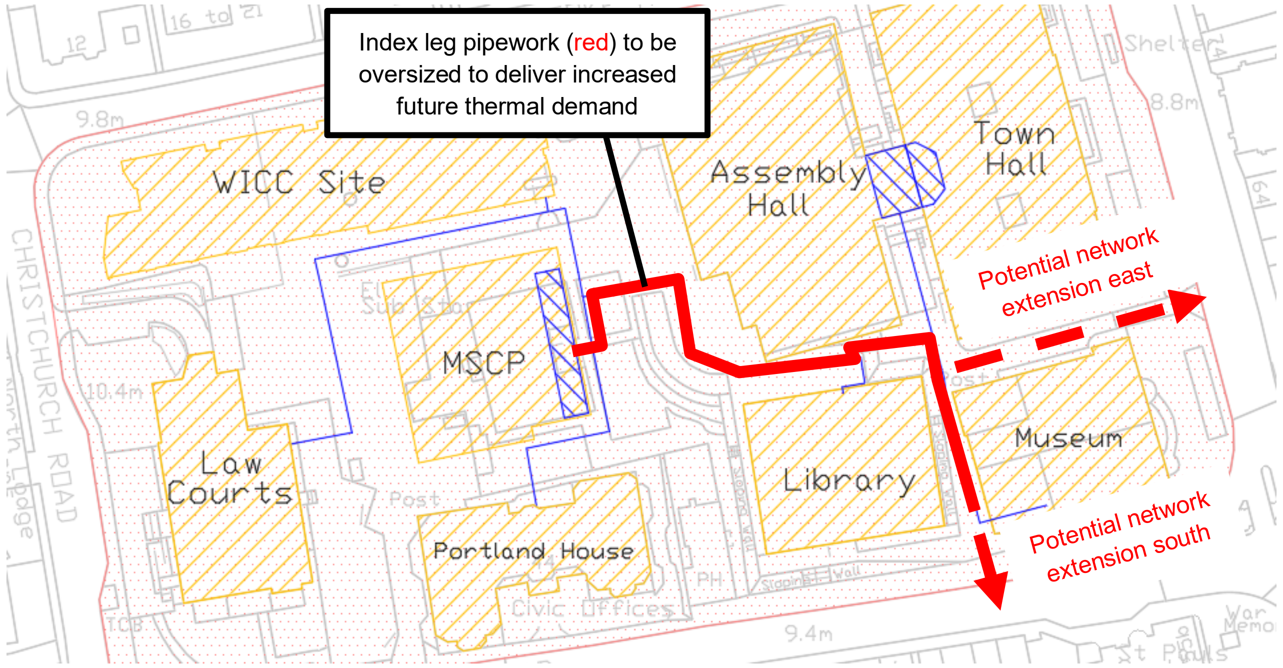


Figure 8-8: Illustration of the index leg that would need to be oversized to enable future extension of a Civic Quarter network

Additional generation capacity would need to be added at an extra energy centre site if it is decided to include additional building connections with thermal demand(s) totalling more than the potential spare capacity of the network, e.g. Worthing Hospital. Connections to additional sites will require further analysis on a case-by-case basis.

[16] Using UKPNs Distributed Generation (DG) online mapping tool

9. Utility Connections

9.1 Electrical Grid

To facilitate a transition to carbon neutral operation, the existing gas-based heating systems are required to be converted to electrical heat pump systems, which can be done either through the installation of ASHPs in each building or via the proposed DEN scheme.

To implement either solution, new or uprated electrical connections are required to increase the peak supply capacity to meet the extra power demand requirements. Preliminary investigations[16] indicate that there is available capacity in the local transformers that serve both the Civic Quarter and Union Place site meaning that no non-standard electrical grid reinforcement works are likely to be required to implement the DEN (to be confirmed through consultation with UKPN).

The costs, however, associated with the implementation of a district scheme are expected to be smaller in comparison to individual ASHP upgrade solution as per Table 9-1 below:

Scenario	Connection Requirements	Preliminary Costs for Civic Quarter
ASHPs located in each building	To facilitate these upgrade works, each building would have to apply to UKPN for their required electrical capacity to install an ASHP, with an estimated cost of up to £65,000 per site	Up to £65,000 per building, totalling £325,000 for the whole site
DEN scheme	Total connections costs are reduced by the reduced number of additional connections or capacity upgrades and reduced overall capacity upgrades as a result of the diversification of the heating demand across the whole site	Up to £65,000 for a single connection

Table 9-1: Comparative electrical connection requirements and preliminary costs for the two alternative carbon neutral operational strategies for the Civic Quarter site

9.2 Gas Grid

To serve the additional gas boiler plant being proposed at the Town Hall plant room, additional peak gas supply capacity will need to be allowed for. As detailed in Table 9-2, it is assumed that no non-standard upgrade works will be required to meet this increased demand, as the reduction in gas demand across the site resulting from the decommissioning of all gas boilers following connections to the DEN.

Once the scope of the network has been defined, a connection application should be made.

Gas Supply Capacity	Peak Civic Quarter Gas Demand
Existing gas boiler systems	1.7 MW total
Developed scenario 1 – OL-GSHP	0.9MW operational 1.1 MW including resilient boiler
Developed scenario 2 - SSHP *(Additionally serving Union Place)*	1.6 MW operational 1.9 MW including resilient boiler

Table 9-2: Civic Quarter existing system and DEN solution peak gas supply capacities

10. Key Risks

The key risks for the implementation of a DEN scheme in the Civic Quarter site are as follows:

Risk Category	Risk Description	Mitigation Strategy
Technical	Heat loads are lower than predicted due to changes to masterplan. Viability of scheme reduced due to reduced heat sales.	Install half hourly bulk gas or heat output meters in buildings with uncertain energy demands - Town Hall and Assembly Hall - to improve data quality.
Technical	One of the preferred technical solutions for the generation of heat, OL-GSHP and gas boilers, proves to be undeliverable on the basis that either reinjection of ground water back into aquifer and consumption on site and / or rejection to the sewer lines is not possible.	Develop a fall-back solution, with the second-best option (from TEM modelling during feasibility stage of works), which for a Civic Quarter only network is a SSHP and gas boiler option, until one a preferred solution is verified and selected for the purpose of defining KPIs can be established prior to tending process.
Technical	The current concept design includes the inclusion of ammonia based refrigerant heat pumps, as they have the benefit of being able to generate high temperatures and have low global warming potential impact.	The additional SHE risks posed by the use of ammonia can be mitigated by ensuring design, construction and operation in a way that reflects the additional risks of this approach, and in line with relevant SHE guidance. Additional technical review(s) will be required.
Commercial	Phase 1 of Union place development is not included within the core district energy scheme and subsequently develops own heating solution(s). Reduces the potential for the network to extend beyond Civic Quarter as thermal density is reduced.	WBC to investigate the potential site viability impact of conditioning the Union place to connect to the DEN site prior to sale to developers. DEN scheme to offer competitive alternative to the anticipated BaU heating systems of ASHP and gas boilers.
Economic	Developed technical solutions at feasibility stage were based upon all customers paying higher heat tariffs then they do currently. Risk that customers do not agree to these terms and the economic case for any developed solution is eroded.	Include all customer stakeholders in project working group. Develop alternative BaU scenarios, based on gas boiler use, gas boiler and social cost use and alternative CO_2 reduction strategy (conversion to ASHP) to demonstrate the value of connecting to a DEN scheme beyond the present-day costs. WBC and BEIS to consult with all stakeholders with the intention of agreeing Heads of Terms prior to the tendering process.
Commercial	Failure to secure public or private funding - business case for investment relies on mix of future cashable benefits which are difficult to bank and non-cashable benefits. Both developed solutions rely on grant funding to produce an IRR of 6%.	WBC to establish the required rate of return for the project to be considered a viable investment. Ensure business case is robust and seek ways to minimise cost and maximise cashable benefits - make case for use of mechanisms such as s106 and CIL as well as external grant funding. Review available contributions through submitted S106, feed into feasibility work. Secure connection charges from customers. Apply for HNIP gap funding.

Table 10-1: The key risks as identified within the full risk report.

A full risk register has been produced alongside this report, refer to Appendix M (separate file).

11. Conclusions

Based on the above analysis, AECOM's conclusion is that **the potential for delivering a heat network on the Civic Quarter site is high**, both against the present-day counterfactual of gas boiler operation as well as a notional counterfactual scenario in which all buildings convert to individual air source heat pumps in the near future.

This is primarily due to the close proximity of numerous buildings with relatively high heat demands resulting in a high heat density, the headline indicator for heat network feasibility. Furthermore, the WICC development presents an opportunity to install the required infrastructure and, while there are constraints and risks, we believe these can be mitigated through the design.

11.1 Technical Solution

The optimal technical solutions are based upon the majority of the heat (>90%) required coming from a high efficiency heat pump system, with the two best being:

- An open loop ground source heat pump array installed within the WICC development boundary, abstracting and reinjecting ground water from the chalk aquifer beneath the Civic Quarter site. This solution offers CO_2 reductions of 75% (min.), as generational capacity may be constrained by the available groundwater yield from a single borehole (to be confirmed via a groundwater pumping test, see Section 12.1); or
- A sewer source heat pump system, capturing waste heat from the sewer system running adjacent to the Union Place development site. This solution offers CO_2 reductions of up to 90%, as the flow within the sewer is estimated to be high enough to meet all of the site heat requirements.

Both solutions incorporate backup gas boilers to provide a low-cost solution to meet peak heat demands and ensuring resilient supply.

The environmental and economic performance of the network can be further improved by:

- **Inclusion of the Union Place development on the network.** Doing so will increase the thermal demand served by the network by c. 50%, and will require larger generational plant items, plant space (with the optimal solution being to utilise space within the Union Place site). However, it will also come with additional challenges, such as increasing the level of programme risk as the network and new development will need to be delivered in parallel, likely by multiple stakeholders; and
- **Lowering the heating system flow and return temperatures within each building;** Implementing the changes within the different buildings on site does pose technical challenges, but the costs to implement are anticipated to be adequately covered by the level cost savings achieved from the improved heat pump generational efficiencies.

Further improvement to the environmental performance of the network can be achieved at an additional cost to the network by:

- **Including a local cooling network delivering waste coolth generated by operating the heat pumps to the Library, Law Courts and WICC site.** Doing so will increase the gross efficiency of the heat pumps, although without the availability of more plant space within the Civic Quarter, a resilient source of supply cannot be included and all existing centralised chiller plant at each site should be retained.

11.2 Environmental Benefits

From WBCs perspective, the implementation of either scheme would substantially reduce the carbon emissions associated with the heating systems of their 5 Civic Quarter Sites (Town Hall, Assembly Hall, Museum, Portland House and WICC site).

	BaU systems	Developed scheme 1 – OL-GSHP	Developed scheme 2 – SSHP
2030 Carbon Emissions	405	119	76
2050 Carbon Emissions	401	89	30

Table 11-1: Comparative 2030 Carbon Emissions of existing gas boilers and developed DEN scenarios

This is illustrated in Figure 11-1 below, which shows a year on year increase in the level of carbon saved in accordance with the anticipated continued decarbonisation of the UK power grid. Abatement of the remaining carbon emissions, required to achieve carbon neutral operation of the WBC / A&WC building stock by the 2030 target, can be achieved using off-site carbon offsetting measures. These are covered in detail in the Carbon Neutral report.

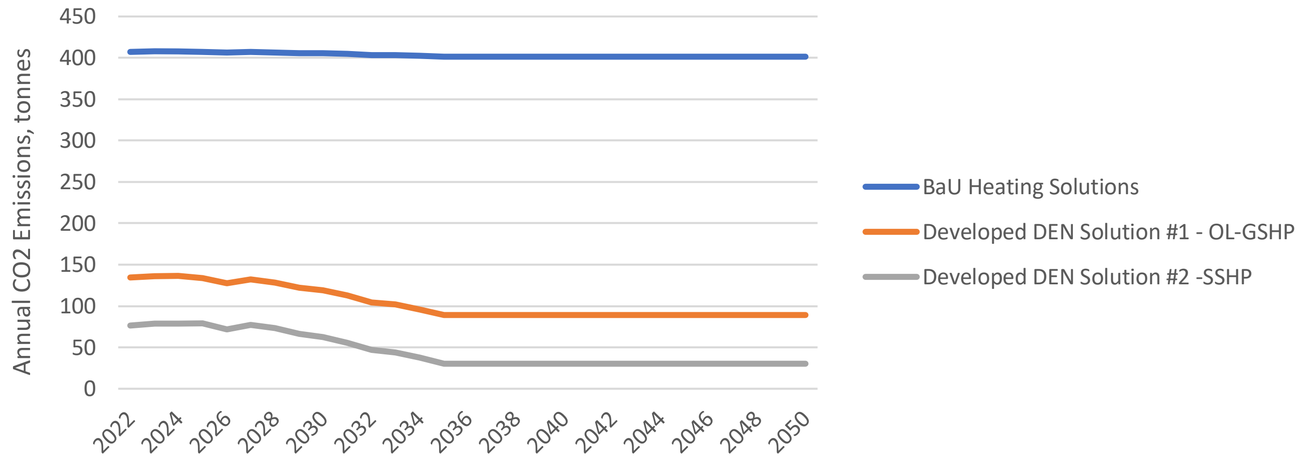


Figure 11-1: Graph illustrating the annual and cumulative reduction in carbon emissions associated with the provision of heating in the Civic Quarter site, shown as a % reduction form the continued use of gas boilers

In the longer term, as the heating provision in the preferred option is almost entirely derived from electrical means, the scheme could become carbon neutral in its own operation in the future should the UK power grid become CO_2 neutral and resilient plant is changed to electrical generation.

11.3 Comparison to Building Level Systems

The identified alternative solution to achieving carbon neutral operation is the conversion of all heating systems to local ASHPs. Against this alternative, the implementation of a DEN scheme has the following advantages and disadvantages:

Advantages:

- Potential to achieve higher carbon savings through the ability to access sources of heat that deliver higher levels of efficiency;
- Single project to address all buildings on the Civic Quarter site in one go, this is likely to mean that the heating systems of the buildings will be decarbonised sooner which will save more overall carbon;
- The implementation and maintenance of a low carbon heating solution becomes the responsibility of a specialist Energy Supply Company (ESCo), and does not lie with the individual building operators, this is likely to mean more effective operation;
- Lower capital and operating cost to all building operators;
- HNIP capital grants can be accessed to finance the project;
- An additional carbon benefit, which has not been quantitively captured within the modelled CO_2 abatement analysis, is that larger scale heat pump installations (such as that included within the preferred scheme) are able to better make use of heat-pump refrigerants with significantly lower Global Warming Potential (GWP). The outline designs currently allow for the use of Ammonia as the refrigerant, which has GWP rating of zero. Traditional refrigerants, typical to smaller heat pump systems that are suited to building level operation, range 1,100 (R401-A) to 2,600 (R402-A)[17]; and
- Provide job growth in the local area.

Disadvantages:

- Disruptive external works associated with the installation of distribution network within the Civic Quarter site;
- Distribution network results in higher thermal losses associated with the delivery of heat compared to individual building solutions; and
- The associated development timeline for the creation of a network is highly likely to be too long to achieve the current cut-off date for the current Renewable Heat Incentive (RHI) scheme, due to end in March 2022. However, installing heat pumps prior to this deadline is more achievable at building level.

[17] Refrigerant GWP source: https://www.engineeringtoolbox.com/Refrigerants-Environment-Properties-d_1220.html

11.4 Customer Benefits

The DEN represents the lowest cost solution to customers to decarbonise all existing customers' heating systems, although it does represent an increase in costs against the continued use of the currently installed systems.

However, it is not likely that the total cost of using gas boilers will continue in the manner that it does currently. Figure 11-2 below illustrates the different levels of heat tariff rates paid by buildings within the Civic Quarter, and a potential tariff escalation scenario based upon the implementation of policy drivers.

Against this policy driven 'do nothing' business as usual scenario, the implementation of DENs can be shown to offer lower WLC costs.

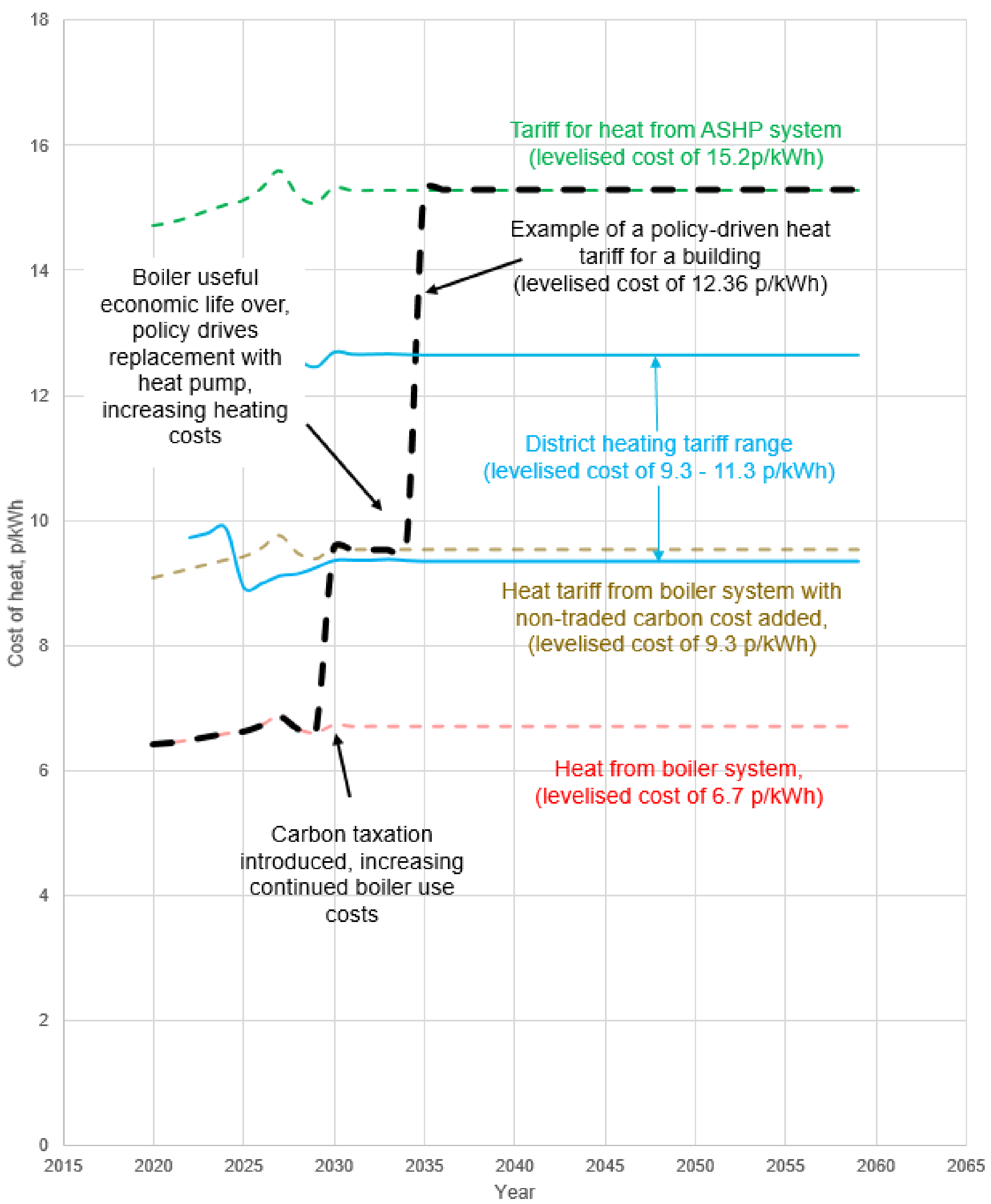


Figure 11-2: A potential resultant long-term 'business as usual' heat tariff scenario compared against the developed DEN solutions

12. Next Steps

To further progress the development of any scheme, the following technical and commercial aspects need to be investigated.

12.1 Technical Development

12.1.1 Improved Energy Data Collection

In lieu of historical data being available, the energy demands for the Town Hall and Assembly hall have been based upon thermal benchmarks, with these two buildings equating to 46% of the total Civic Quarter heat demand.

To reduce the levels of risk around the design and cash flow elements of the developed solutions, half hourly gas or heat consumption data loggers should be installed within the Town Hall and Assembly Hall boiler system in time for the resumption of normal building operation (following the cessation Covid-19 'lockdown' temporary working measures).

12.1.2 Building Heating System Adaptation Works

This report has identified the potential economic and environmental benefit that could arise from the lowering the heating system temperatures in each building in the Civic Quarter. To date, the costs of implementing these alterations has been based upon estimates and have been included within the cost plan for the DEN.

Should WBC wish to proceed with the intention of including this element of work within the project, and all building stakeholders are happy proceed with undertaking the appropriate measures, more detailed studies would be required to confirm the measures, costs, viability and benefits in each location to inform a business case for investment.

12.1.3 Confirmation of the OL-GSHP System

This report has identified that an Open-Loop GSHP solution represents the best opportunity to implement a low carbon DEN serving the Civic Quarter site only. Such a system can take a minimum of 12 months to implement, depending on the infrastructure requirements & availability (including negotiations with the Environment Agency on abstraction and recharge consents), and as such can put the geothermal energy system's implementation on the critical path of the project's procurement. Consequently, the following phased approach is proposed:

Stage 1 (completed as part of this project) – Feasibility Study Phase; identification of proposed locations for the boreholes. Refer to Appendix F for full study outcome.

Stage 2 – Confirmation from the EA and Southern Water that there a viable solution to mitigate the potential risk of reinjection into the aquifer causing localised flooding in Worthing.

Stage 3 – Should the council wish to progress with the solution, tender preparation, contractor procurement, supervision and management of the drilling, installation and pumping test to confirm the hydrogeological properties;

Stage 4 – Detailed hydrogeological and impact assessment;

Stage 5 – Licensing and permitting stage; and

Stage 6 – Design, specification, and construction of borehole manholes, pumps, interconnecting pipework, heat exchanger, electrical system and controls systems.

12.1.4 Confirmation of the SSHP System

This report has identified that a SSHP solution represents the best opportunity to implement a low carbon DEN serving a network that covers the Civic Quarter site as well as others across Worthing Town Centre. To implement such a solution, the following phased approach is proposed:

Stage 1: Undertake detailed feasibility assessment, including the installation of flow and temperature monitoring equipment within the identified sewer.

Stage 2: Obtain agreements with southern water for the installation works and ongoing system operation.

Stage 3: Ensure allowances for the placement of the necessary wet well and either pumping station or entire energy centre are agreed with the necessary Union Place stakeholders.

Stage 4: Design, specification, and construction of sewer interface equipment, manholes, pumps, interconnecting pipework, heat exchanger, electrical system and controls systems.

12.1.5 Utility Connection Applications

Once the core scheme scope has been agreed, utility network connection applications should be submitted to confirm the necessary works and fees for increased capacity connections to both the power network (operated by UKPN) and gas network (operated by SGN).

12.2 Commercial Development

12.2.1 Selection of a Preferred Technical Solution and Development of the Outcomes Based KPI Specifications

Based on consultation with WBC and BEIS throughout the project, it is anticipated that WBC will seek any DEN to be procured via a Key Performance Indicators (KPI) -based procurement exercise. Should this occur, it will result in the preferred technical solution to be identified by the installation contractor chosen to implement the scheme. This decision will be dictated by the following KPIs[18]:

- Marginal cost of heat sent from the EC;
- Seasonal performance of heat pumps;
- LZC heat proportion of total heat generated; and
- Carbon intensity of heat generated.

To set the above KPI criteria, prior to seeking procurement the following different factors need to be considered:

1) WBC's requirement for on-site CO_2 savings and potential means of offsetting emissions off-site (to meet carbon neutrality commitments);
2) The acceptable level of increased operational costs for the provision of heating within the different building operation stakeholders (WBC, WSCC, MoJ and NHS);
3) The required (if any) rate of economic return for WBC's to invest capital funds into any DEN scheme; and
4) The anticipated expansion of the DEN scheme beyond the Civic Quarter site in both the short term (i.e. inclusion of Union Place in the initial scheme) and the long term (I.e. inclusion of the additional heating loads identified in the heat mapping and masterplanning report summarised in Section 7.4).

To be able to define the desired KPIs of the DEN, the technical viability of the two identified heat pump solutions needs to be verified, and a preferred solution selected. Figure 12-1 (overleaf) illustrates a potential decision process route map to be undertaken to undertake this selection process.

12.2.2 Funding Routes

At the time of writing, two UK-treasury financed grant funding schemes are operational which are applicable to the proposed DEN scheme.

Once the level of funding required to achieve the chosen solution has been identified, a funding application can be made.

12.2.2.1 Heat Networks Investment (HNIP) Programme

Both of the developed solutions identified within this report have estimated unfunded project-IRRs that are likely to be lower than that required by WBC for investment purposes. This is typical of DEN projects across the county and is what the Heat Networks Investment Programme (HNIP) was set up to address. Its purpose is to distribute grant funding and low-interest loans (paid by the UK Treasury) to DEN projects that require a level of gap-funding to be considered economically attractive enough to attract the capital investment required to fund them.

At this stage of the project, it is estimated that the preferred solution requires a total Gross Grant Equivalent (GGE) intervention of between £0.8m and £1.3m to achieve an IRR of 6%, which includes an allowance for the commercialisation phase of development. A full application for the required grant is due to be submitted for October 2020.

12.2.2.2 Renewable Heat Incentive (RHI)

Both of the developed solutions identified within this report are also eligible for the RHI scheme, which provides an additional revenue stream based upon the amount of thermal energy generated by a heat pump system operating above at high efficiency. The incentives last for 20 years following the first payment date, and at the time of writing the scheme is due to cease in March 2022, at which point any system is required to be both operational and delivering heat to one or more customers to be eligible.

Based on the above cut-off date being earlier than the expected heat on date for any DEN in the Civic Quarter site (which is dependent on the construction timelines of the WICC development site), RHI funding has not been considered within the assessments contained within this report due to the considerable level of programming risk it would create.

However, it is worth noting that the level of incentives available to either a GSHP systems or SSHP are sufficient enough to negate the requirement for any customers within the Civic Quarter to pay above their current gas-boiler thermal generation costs (BaU Scenario 1 – Do Nothing) for the first 20 years of the schemes operation.

[18] Based on the draft KPI schedule produced by the HNDU.

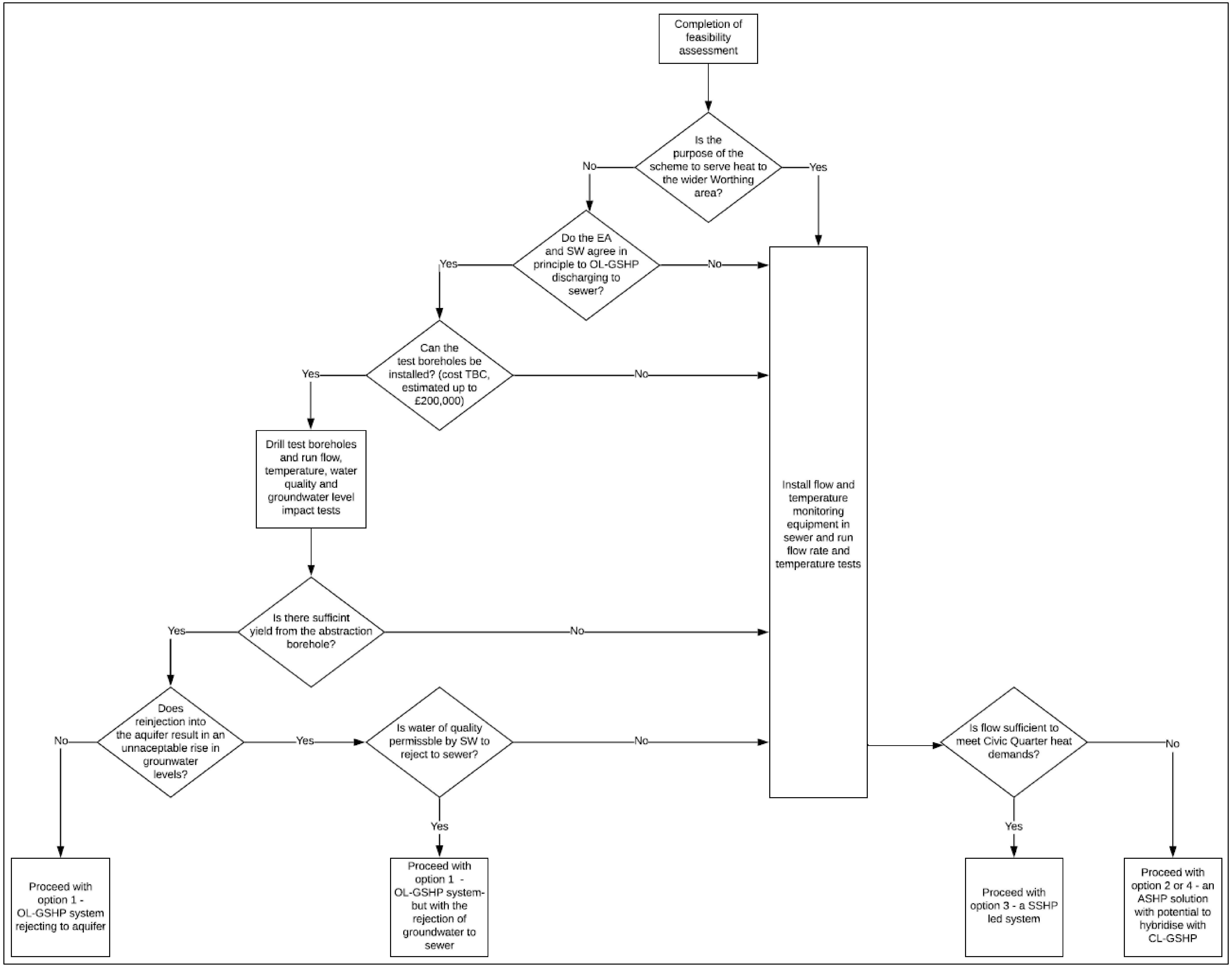


Figure 12-1: Potential Decision Tree to Identify a Preferred Solution Following Completion of this Report

12.3 Critical Dates

To ensure that any scheme can provide heating services in time for the completion of the WICC development, the following delivery programme has been developed for commercialisation and construction elements of the project.

The programme includes two potential delivery routes, one in which the development of the DEN is linked directly to that of the WICC site, and another where it is delivered independently.

ID	Task Name	Duration	Start	Finish
1	**Worthing CQHN**	**618 days**	**Wed 01/04/2**	**Fri 12/08/22**
2	Issue Draft Final Report (WP1&3)	0 days	Fri 19/06/20	Fri 19/06/20
3	M/Plan & F/Study (WP 1&3)	3.85 mor	Wed 01/04/2	Thu 16/07/20
4	Final Report (WP1&3)	0 days	Thu 16/07/20	Thu 16/07/20
5	Report Presentation	1 day	Fri 17/07/20	Fri 17/07/20
6	Route to Market	0 days	Thu 07/05/20	Thu 07/05/20
7	WBC Internal Awareness discussions	15 days	Mon 11/05/2	Fri 29/05/20
8	HNIP Initial Application	0 days	Tue 09/06/20	Tue 09/06/20
9	HNDU PM & Stakeholder Funding Ap	0 days	Fri 03/07/20	Fri 03/07/20
10	MoU discussions	20 days	Mon 06/07/2	Fri 31/07/20
11	Internal Heat Network Delivery Worl	0 days	Wed 29/07/2	Wed 29/07/2
12	HNDU Technical/Legal/Commercial /	0 days	Fri 31/07/20	Fri 31/07/20
13	ESCo/Investor day	0 days	Thu 10/09/20	Thu 10/09/20
14	Technical/Legal/Commercial Procure	40 days	Mon 06/07/2	Fri 28/08/20
15	HoT's	20 days	Mon 07/09/2	Fri 02/10/20
16	Concession ITT Production	20 days	Mon 31/08/2	Fri 25/09/20
17	Business Case Production & HNIP Inp	20 days	Mon 31/08/2	Fri 25/09/20
18	HNIP Application	0 days	Fri 02/10/20	Fri 02/10/20
19	HNIP Approvals	100 days	Fri 02/10/20	Thu 18/02/21
20	Offtake Negotiations	40 days	Mon 12/04/2	Fri 04/06/21
21	Competitive Dialogue Tender Proces	28 wks	Mon 28/09/2	Fri 09/04/21
22	Approvals/Pricing Agreement	90 days	Mon 12/04/2	Fri 13/08/21
23	Contract Award	0 days	Fri 13/08/21	Fri 13/08/21
24	Construction	12 mons	Mon 13/09/2	Fri 12/08/22

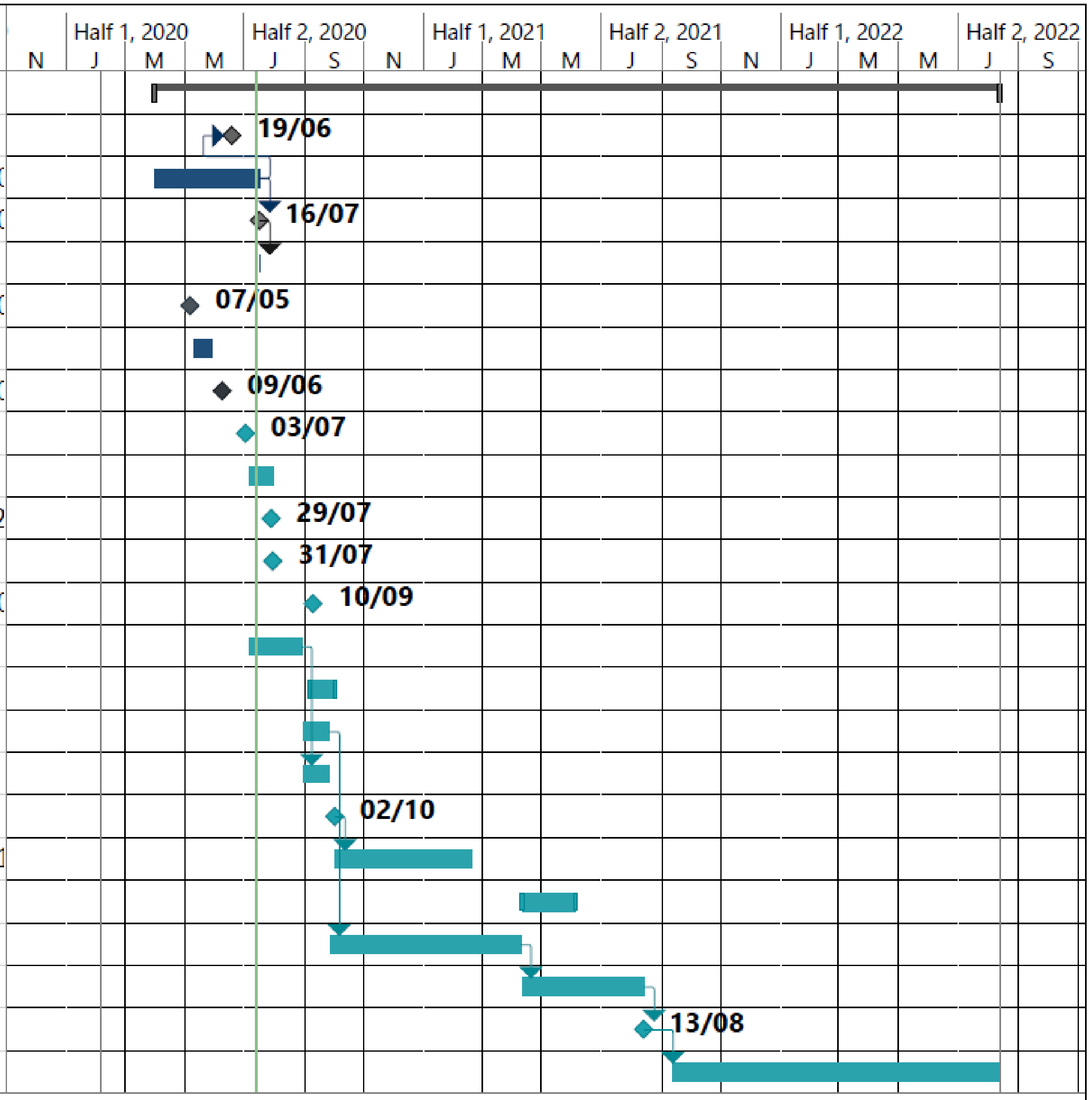


Table 122-1: Delivery programme for the DEN, current at time of writing (Rev07)

Appendix A - Data Collected

The following matrix details the information that was obtained by AECOM during the undertaking of this project. As the majority of the project was undertaken during April to July 2020 during the global COVID-19 pandemic, no additional building surveys were conducted, therefore all information gathered was done so through remote contact with the different stakeholders.

Where data was either unavailable due to limitations surround site access or staff absences, benchmark data developed by AECOM for the purposes of analysing DEN schemes shall be used.

These assumptions are detailed in Appendix I.

Key

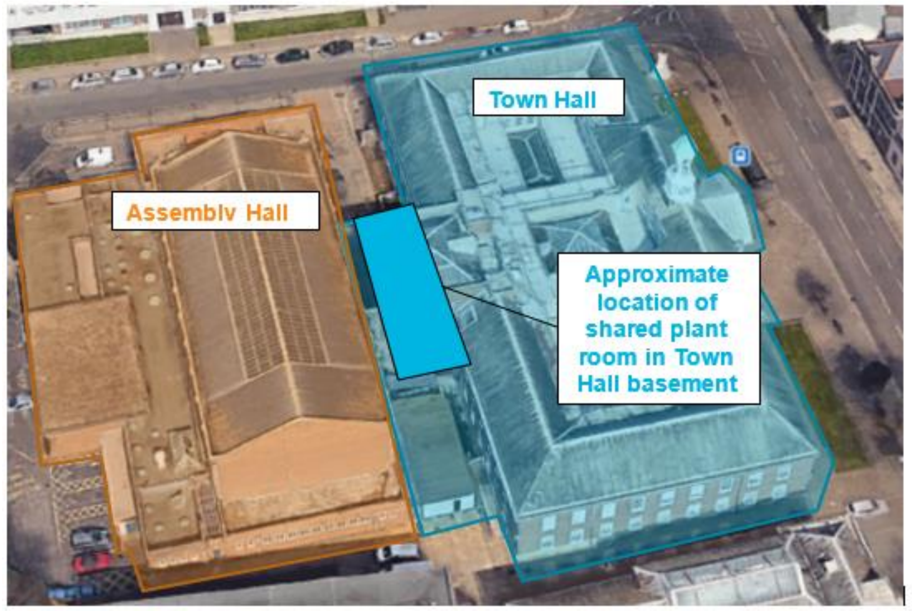
•	Up-to-Date Info. Received by AECOM
	Hisorical Info. Received, Up-to-Date Requested
	Info. Outstanding
×	Info. Not Available
–	Info. Not Required

	Energy Data		System Data											Cost Data				
	Current Gas Consumption	Current Elec. Consumption	Layout Drawings	Heating Generation Plant Details	Heating Emitter Design	Heating Flow & Return Temperatures	Heating Schematic Drawings	Cooling Generation Plant Details	Cooling Emitter Design	Cooling Flow & Return Temperatures	Cooling Schematic Drawings	Power Schematic Drawings	Renovation Plans	Current Gas Costs	Current Elec. Costs	Plant Capital Costs	Plant Operational Costs	Plant Replacement Cycles
Worthing Town Hall	×	•	•	•	•	•		•	×	×			•	•	•		•	•
Portland House	•	•	•	•	•	•		•	×	×			•	•	•		•	•
Assembly Hall	×	•	•	•	•			–	×	×			•	•	•		•	•
Museum & Art Gallery	•	•						×									•	
Library	•	•			•	•		•		•			•	•	•			
Law Courts	•	•	•	•				•					•	•	•			
WICC	•	•	•	•	•	•		–	•	•			–	•	•	×	×	×
Union Place	×	×	×	•	×	×	×	×	×	×	×	×	×	×	×	×	×	×

Appendix B - Building Data

B.1 Town Hall and Assembly Hall

The Town Hall and Assembly Hall are two halves of the same building, which share the same centralised plant room located in the basement of the Town Hall. The site is a Grade II listed monument.

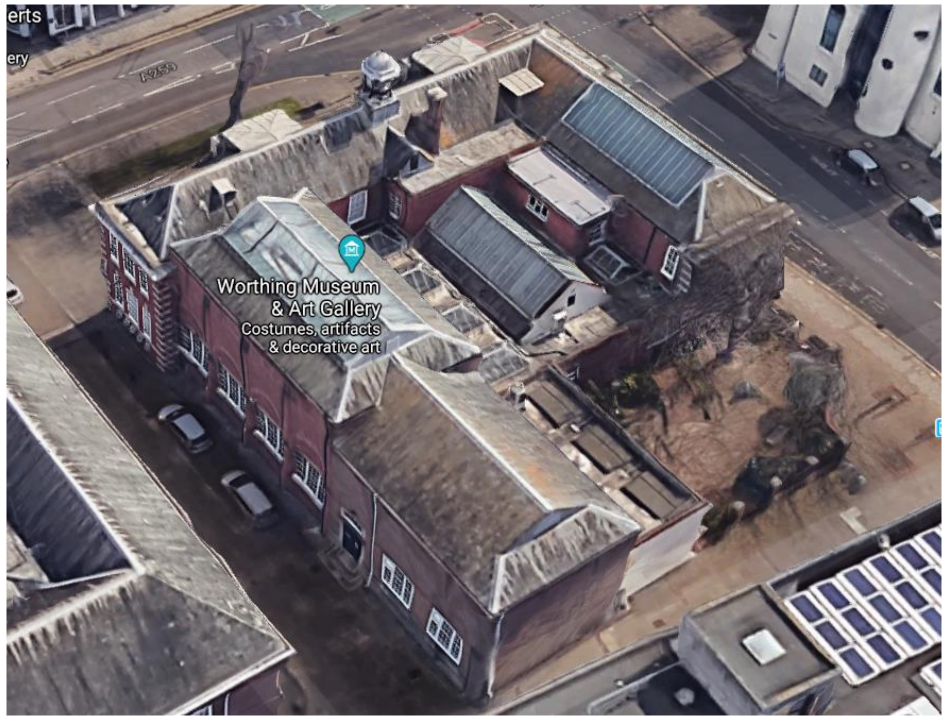


	Town Hall	Assembly Hall
Ownership	Worthing Borough Council	Worthing Borough Council
Operation	Worthing Borough Council	Worthing Theatres Trust
Organisation carbon commitments	Carbon neutral by 2030	
Primary Use	Offices and Council Chambers	Theatre
Space Heating Plant	120kW Gas boilers	120kW Gas boilers
Space Heating Flow/Return Temp.	74 / 70°C	74 / 70°C
Space Heating Emitters	Radiators, AHU FCU	Radiators
Hot Water Plant	Shared gas fuelled calorifier	
Cooling Plant	Air conditioning units – server room and isolated office spaces	None
Electrical Substation	Shared LV incomer	
Planned Renovations	Secondary glazing	None
Current heating system like-for-like replacement cost	£200,000	
Current heating system annual maintenance cost	£3,798 (2019) £4,844 (2020)	

B.2 Portland House

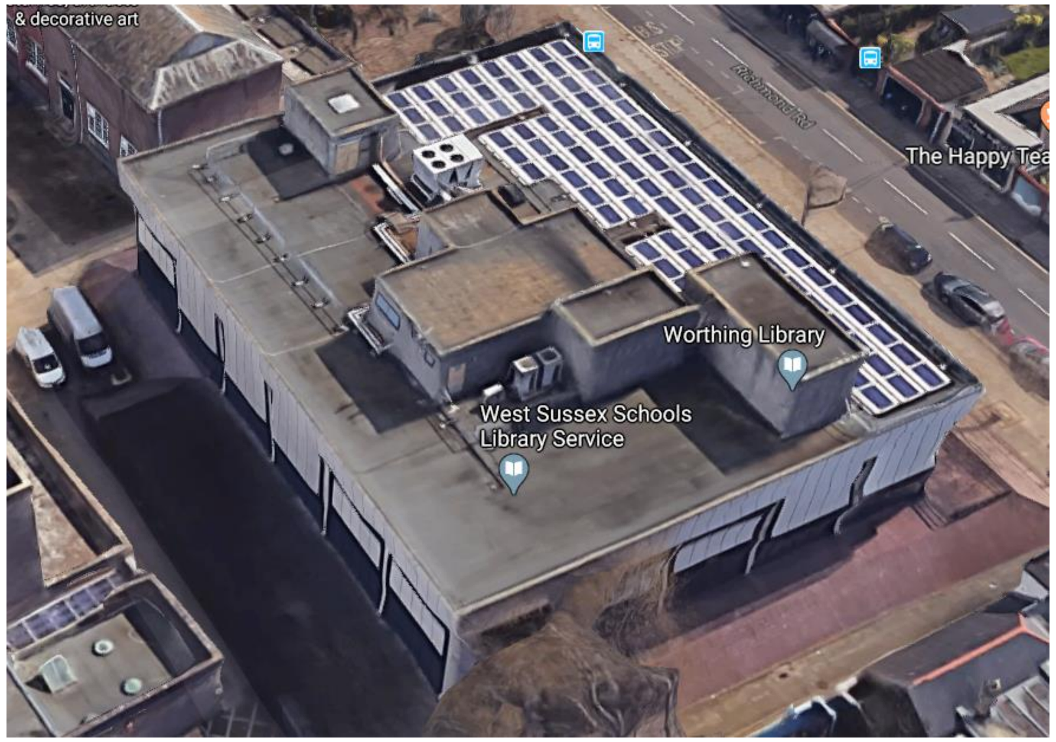
	Portland House
Ownership	Worthing Borough Council
Operation	Worthing Borough Council
Organisation Carbon Commitments	Carbon neutral by 2030
Primary Use	Offices
Heating Plant Room Location(s)	Fourth floor
Space Heating Plant	450kW Gas boilers
Space Heating Flow/Return Temp.	74 / 70°C (assumed)
Space Heating Emitters	Radiators, perimeter heating
Hot Water Plant	Gas fuelled calorifier
Cooling Plant	Air conditioning units – server room and isolated office spaces
Electrical Substation	Own LV incomer
Planned Renovations	Triple glazing throughout
Current heating system annual maintenance cost	£5,209 (2019) £4,468 (2020)

B.3 Museum and Art Gallery



	Museum and Art Gallery
Ownership	Worthing Borough Council
Operation	Worthing Theatres Trust
Organisation Carbon Commitments	Carbon neutral by 2030
Primary Use	Museum and Art Gallery
Heating Plant Room Location(s)	Basement
Space Heating Plant	Gas boilers, VRV units, thermal capacities unknown
Space Heating Flow/Return Temp.	TBC; assumed 80 / 60°C
Space Heating Emitters	Radiators, VRV units, warm air heaters
Hot Water Plant	TBC; assumed gas-fired calorifier
Cooling Plant	VRV units
Electrical Substation	Own LV incomer
Planned Renovations	Extension (café), internal reconfiguration and MEP reconfiguration
Current heating system annual maintenance cost	£2,654 (2019) £2,111 (2020)

B.4 Library



	Library
Ownership	West Sussex County Council
Operation	West Sussex County Council
Organisation Carbon Commitments	Carbon neutral by 2030
Primary Use	Library
Heating Plant Room Location(s)	Basement
Cooling Plant Room Location(s)	Roof-space
Space Heating Plant	Gas boilers, thermal capacity unknown
Space Heating Flow/Return Temp.	80 / 60°C
Space Heating Emitters	AHU FCU, radiators
Hot Water Plant	Gas fired calorifier
Cooling Plant	Centralised air-cooled chiller
Electrical Substation	Own LV incomer
Planned Renovations	MEP renovation works (2021 on-site commencement)

B.5 Law Courts

	Law Courts
Ownership	Ministry of Justice
Operation	Ministry of Justice
Organisation Carbon Commitments	50% reduction by 2025[19]; Carbon neutral by 2050 (aligned with UK government)[20]
Primary Use	Law Courts
Heating Plant Room Location(s)	Basement
Cooling Plant Room Location(s)	Roof-space
Space Heating Plant	Gas boilers, thermal capacity unknown
Space Heating Flow/Return Temp.	TBC; assumed 80 / 60°C
Space Heating Emitters	TBC; Assumed radiators
Hot Water Plant	TBC; Assumed gas fired calorifier
Cooling Plant	Centralised air-cooled chiller
Electrical Substation	Own LV incomer
Planned Renovations	None

[19] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/692523/carbon-energy-reduction-strategy.pdf

B.6 WICC

	WICC
Ownership	Worthing Borough Council
Operation	National Health Service (NHS)
Primary Use	Clinical Care
Building Age	To be completed 2022
Heating Plant Room Location(s)	Multi story car park, roof space
Cooling Plant Room Location(s)	Roof space
Space Heating Plant	Air source heat pumps, thermal capacity not selected
Space Heating Flow/Return Temp.	35° Flow, Return TBC (assumed 25°C)
Space Heating Emitters	Underfloor heating
Hot Water Plant	Gas boilers, calorifier
Cooling Plant	Air source heat pumps
Electrical Substation	Own LV incomer
Planned Renovations	N/A

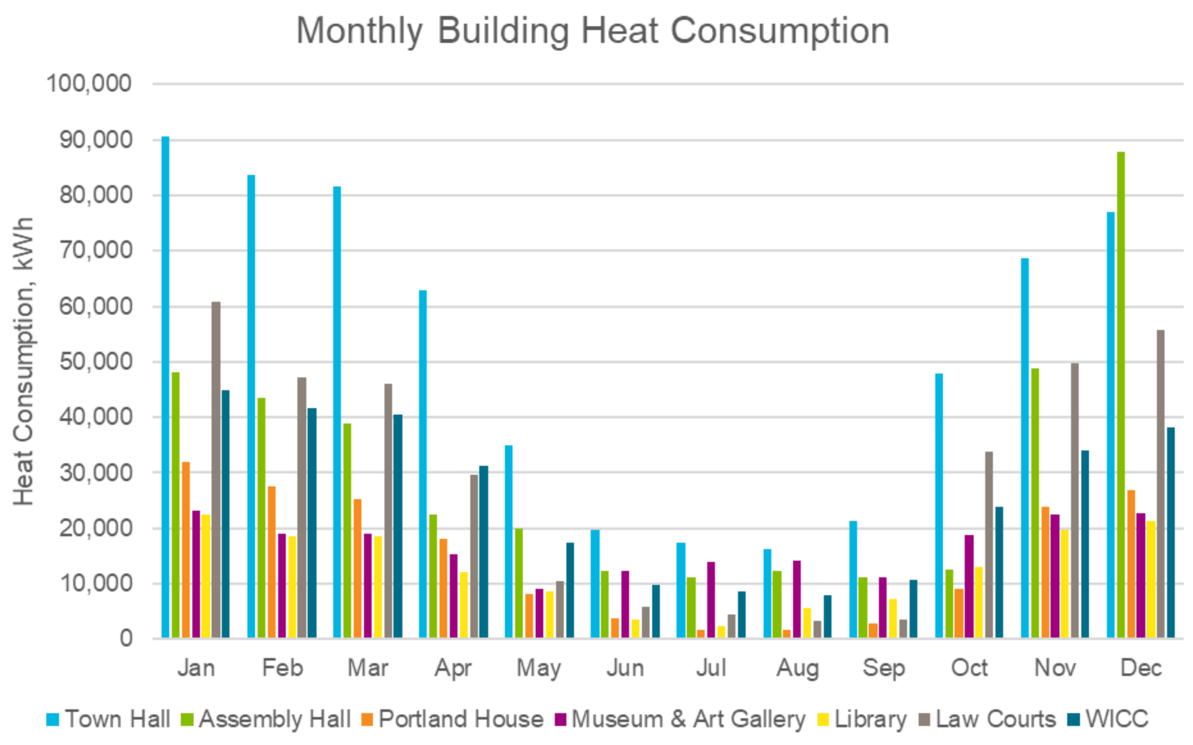
[20] https://www.parliament.uk/documents/commons-committees/environmental-audit/correspondence/190930-MoJ-Response-to-EAC-Net-Zero.pdf

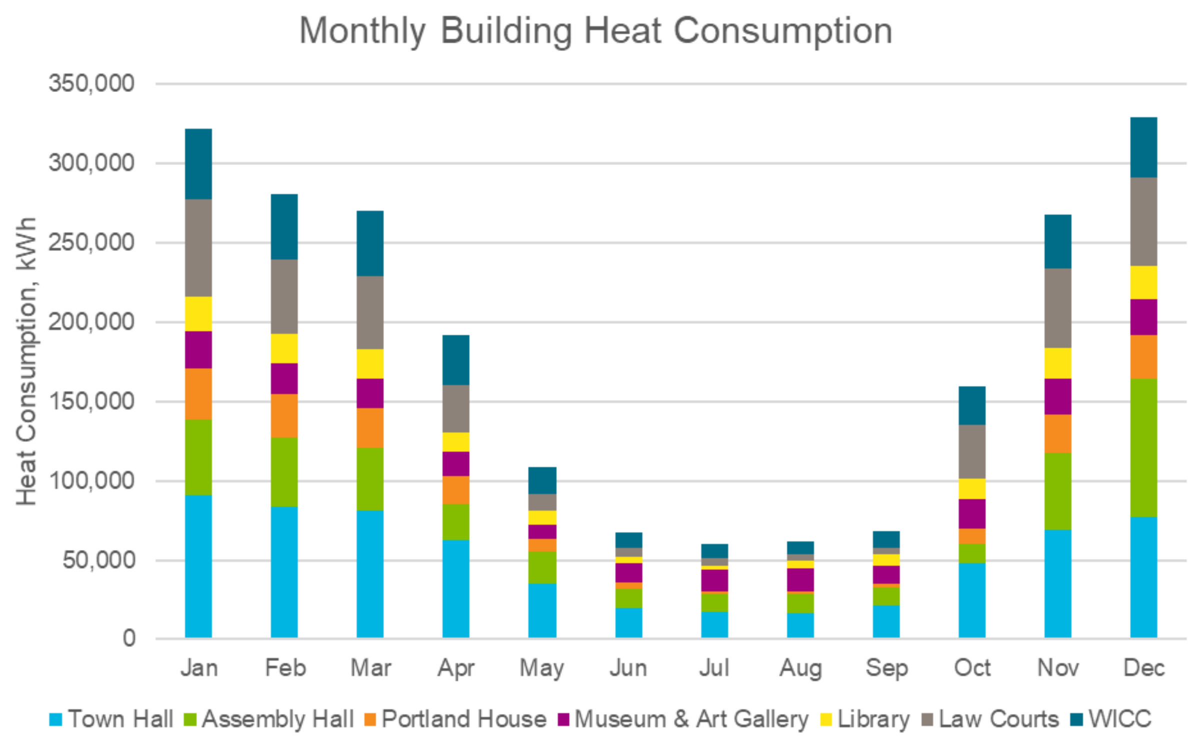
B.7 Union Place

	Union Place
Ownership	Worthing Borough Council (Current), to be sold to private development firms
Operation	TBC
Primary Use	Hotel, retail, cinema, offices
Building Age	To be completed 2022 – 2025
Heating Plant Room Location(s)	Design TBC
Cooling Plant Room Location(s)	Design TBC
Space Heating Plant	Air source heat pumps / gas boilers
Space Heating Flow/Return Temp.	Design TBC; Assumed 60/40°C
Space Heating Emitters	Design TBC; Assumed low temperature
Hot Water Plant	Design TBC
Cooling Plant	Design TBC
Electrical Substation	Design TBC
Planned Renovations	N/A

Appendix C – Energy Data

	Current Heating Demand MWh/year	Peak Heating Demand, kW	Data Source	Current Cooling Demand MWh/year	Peak Cooling Demand, kW	Data Source	Current Power Demand MWh/year	Peak Power Demand, kW	Data Source
Town Hall	620	200	Thermal benchmarks	-	-	Thermal benchmarks	620	155	Metered half-hourly gas consumption
Assembly Hall	370	240	Thermal benchmarks	-	-	Thermal benchmarks	*See town hall*		Metered half-hourly gas consumption
Portland House	180	130	Metered annual gas consumption	-	-	Thermal benchmarks	150	75	Metered half-hourly gas consumption
Museum and Art Gallery	200	60	Metered annual gas consumption	70	110	Thermal benchmarks	60	20	Metered half-hourly gas consumption
Library	150	150	Metered half-hourly gas consumption	-	-	Thermal benchmarks	230	60	Metered half-hourly gas consumption
Law Courts	350	320	Metered half-hourly gas consumption	90	140	Thermal benchmarks	*See town hall*		Metered half-hourly gas consumption
WICC	310	100	Performance specification	40	60	Thermal benchmarks	n/a	n/a	
Sub-total	**2,180**	**850 (diversified)**		**200**	**310**		**1,060**	**280 (diversified)**	
Union Place	930	800	Performance specification	-	-	Thermal benchmarks	n/a	n/a	Performance specification
Total	**3,120**	**1,600 (diversified)**		**200**	**-**		**-**	**-**	





Appendix D – Technical Notes on Lower Secondary Side Heating Temperatures

A series of technical memoranda have been developed to describe the interventions required to lower the building 'secondary side' (i.e. internal system) heating flow and return temperatures. These have been supplied to WBC as separate documents as part of the completion of this study.

Each memo detailed a series of different intervention strategies that could be implemented. The estimated intervention capital cost estimations have been included in this appendix below. Please note that these are outline estimates and more detailed studies would be required to confirm the measures, costs, viability and benefits in each location to inform a business case for investment.

D.1 Town Hall and Assembly Hall

Option 1 – No emitter or BMS upgrades needed:

- Re-balancing of system for lower supply/return: £4000 (£50/hr for two-person team) - SPONS labour rates for system draining, flushing, filling, rebalancing and adjusting BMS set points
- Water Sampling - £1500

Total: £5500.

Option 2 – No emitter upgrades needed:

- Option 1 Costs
- BMS upgrade – £2000

Total: £7500.

Option 3 – Emitter upgrade (additional units added):

- Option 1 costs
- BMS upgrade - £6000
- 30% increase in emitter allowance (using SPONS office building metric of £30/m^2) = £52,000
- Labour cost of installation = £48,000 ((£100/hr for four-person team)

Total: £111,500.

Additional costs may include:

- Pump replacement depending on condition and age of pumps + labour. From a site survey, the pumps look relatively new and are unlikely to need replacement.
- Air Handling Unit coil or whole unit replacement (depending on age/condition/adaptability) + labour.

Next Steps

The next steps are outlined as:

1. Obtain or develop a schematic of the building heating circuit such that the required extent and scope of works can be determined.
2. Obtain or develop a heat loss model for the building including refurbishments to determine the required heating.
3. Monitor internal temperatures throughout a winter period.
4. Produce a scoping document to set out the works required and tender to contractors, including water sampling, pump modification, boiler and control adjustments, and the rebalancing of heating circuits.
5. Undertake system rebalancing. This can be carried out prior to connection to district heating network if the current primary plant (i.e. boilers) has the ability to do so. Alternatively, this will be carried out when the district heating network is ready for connection.

D.2 Portland House

Option 1 – No emitter or BMS upgrades needed:

- Re-balancing of system for lower supply/return: £4000 (£50/hr for two-person team) - SPONS labour rates for system draining, flushing, filling, rebalancing and adjusting BMS set points
- Water Sampling - £1500

Total: £5500.

Option 2 – No emitter upgrades needed:

- Option 1 Costs
- Plus BMS upgrade – £2000

Total: £7500.

Option 3 – Emitter upgrade (additional units added):

- Option 1 costs
- BMS upgrade - £6000
- 30% increase in emitter allowance (using SPONS office building metric of £30/m2) = £24,000.
- Labour cost of installation = £24,000 ((£100/hr for four-person team)

Total: £59,500.

Additional costs may include:

- Pump replacement depending on condition and age of pumps + labour. From a site survey, the pumps look relatively new and are unlikely to need replacement.
- Air Handling Unit coil or whole unit replacement (depending on age/condition/adaptability) + labour.

Next Steps

The next steps are outlined as:

1. Obtain or develop a schematic of the building heating circuit such that the required extent and scope of works can be determined.
2. Obtain or develop a heat loss model for the building including refurbishments to determine the required heating.
3. Monitor internal temperatures throughout a winter period.
4. Produce a scoping document to set out the works required and tender to contractors, including water sampling, pump modification, boiler and control adjustments, and the rebalancing of heating circuits.
5. Undertake system rebalancing. This can be carried out prior to connection to district heating network if the current primary plant (i.e. boilers) has the ability to do so. Alternatively, this will be carried out when the district heating network is ready for connection.

D.3 Museum and Art Gallery

This section provides high level cost estimates from the limited information that has been received. The costs estimates have adopted the following assumptions:

- All BMS costs listed assume that a heating compatible BMS has been installed. This section does not include a cost for the new BMS installation.
- The options assume that the two current heating systems have been combined into one system. This section does not include a cost for the works required to combine the central and VRF system.

Option 1 – No emitter or BMS upgrades needed:

- Re-balancing of system for lower supply/return: £4000 (£50/hr for two-person team) - SPONS labour rates for system draining, flushing, filling, rebalancing and adjusting BMS set points
- Water Sampling - £1500

Estimated Total: £5500.

Option 2 – No emitter upgrades needed:

- Re-balancing of system for lower supply/return: £4000 (£50/hr for two-person team) - SPONS labour rates for system draining, flushing, filling, rebalancing and adjusting BMS set points
- Water Sampling - £1500
- BMS upgrade – £2000

Estimated Total: £7500.

Option 3 – Emitter upgrade (additional units added):

- Re-balancing of system for lower supply/return: £4000 (£50/hr for two-person team) - SPONS labour rates for system draining, flushing, filling, rebalancing and adjusting BMS set points
- Water Sampling - £1500
- BMS upgrade - £6000 (cost assumes heating compatible BMS has been installed – does not include cost of new BMS installation)
- 30% increase in emitter allowance (using SPONS office building metric of £30/m^2) = £25,500.
- Labour cost of installation = £26,000 ((£100/hr for four-person team)

Estimated Total: £63,000.

Additional costs may include:

- Pump replacement depending on condition and age of pumps + labour. From a site survey, the pumps look relatively new and are unlikely to need replacement.
- Air Handling Unit coil or whole unit replacement (depending on age/condition/adaptability) + labour.

Next Steps

The next steps are outlined as:

1. Obtain or develop a schematic of the building heating circuit such that the required extent and scope of works can be determined.
2. Obtain or develop a heat loss model for the building including refurbishments to determine the required heating.
3. Monitor internal temperatures throughout a winter period.
4. Produce a scoping document to set out the works required and tender to contractors, including water sampling, pump modification, boiler and control adjustments, and the rebalancing of heating circuits.
5. Undertake system rebalancing. This can be carried out prior to connection to district heating network if the current primary plant (i.e. boilers) has the ability to do so. Alternatively, this will be carried out when the district heating network is ready for connection.

D.4 Library

Option 1 – No FCU or BMS upgrades needed:

- Re-balancing of system for lower supply/return: £4000 (£50/hr for two-person team) - SPONS labour rates for system draining, flushing, filling, rebalancing and adjusting BMS set points
- Water Sampling - £1500

Estimated Total: £5500.

Option 2 – No FCU upgrades needed:

- Re-balancing of system for lower supply/return: £4000 (£50/hr for two-person team) - SPONS labour rates for system draining, flushing, filling, rebalancing and adjusting BMS set points
- Water Sampling - £1500
- BMS upgrade – £2000

Estimated Total: £7500.

Option 3 – FCU and BMS upgrade (additional units added):

- Re-balancing of system for lower supply/return: £4000 (£50/hr for two-person team) - SPONS labour rates for system draining, flushing, filling, rebalancing and adjusting BMS set points
- Water Sampling - £1500
- BMS upgrade - £6000
- 40% increase in emitter allowance (using SPONS FCU office building metric of £25/m^2) = £35,000
- Labour cost of installation = £40,000 ((£100/hr for four-person team)

Estimated Total: £86,500.

Additional costs may include:

- Pump replacement depending on condition and age of pumps + labour. From a site survey, the pumps look relatively new and are unlikely to need replacement.
- Air Handling Unit coil or whole unit replacement (depending on age/condition/adaptability) + labour.

1. Next Steps

The next steps are outlined as:

1. Obtain or develop a schematic of the building heating circuit such that the required extent and scope of works can be determined.
2. Obtain or develop a heat loss model for the building including refurbishments to determine the required heating.
3. Monitor internal temperatures throughout a winter period.
4. Produce a scoping document to set out the works required and tender to contractors, including water sampling, pump modification, boiler and control adjustments, and the rebalancing of heating circuits.
5. Undertake system rebalancing. This can be carried out prior to connection to district heating network if the current primary plant (i.e. boilers) has the ability to do so. Alternatively, this will be carried out when the district heating network is ready for connection.

D.5 Law Courts

Option 1 – No emitter or BMS upgrades needed:

- Re-balancing of system for lower supply/return: £4000 (£50/hr for two-person team) - SPONS labour rates for system draining, flushing, filling, rebalancing and adjusting BMS set points
- Water Sampling - £1500

Estimated Total: £5500.

Option 2 – No emitter upgrades needed:

- Re-balancing of system for lower supply/return: £4000 (£50/hr for two-person team) - SPONS labour rates for system draining, flushing, filling, rebalancing and adjusting BMS set points
- Water Sampling - £1500
- BMS upgrade – £2000

Estimated Total: £7500.

Option 3 – Emitter upgrade (additional units added):

- Re-balancing of system for lower supply/return: £4000 (£50/hr for two-person team) - SPONS labour rates for system draining, flushing, filling, rebalancing and adjusting BMS set points
- Water Sampling - £1500
- BMS upgrade - £6000
- 30% increase in emitter allowance (using SPONS office building metric of £30/m^2) = £25,500.
- Labour cost of installation = £26,000 ((£100/hr for four-person team)

Estimated Total: £63,000.

Additional costs may include:

- Pump replacement depending on condition and age of pumps + labour. From a site survey, the pumps look relatively new and are unlikely to need replacement.
- Air Handling Unit coil or whole unit replacement (depending on age/condition/adaptability) + labour.

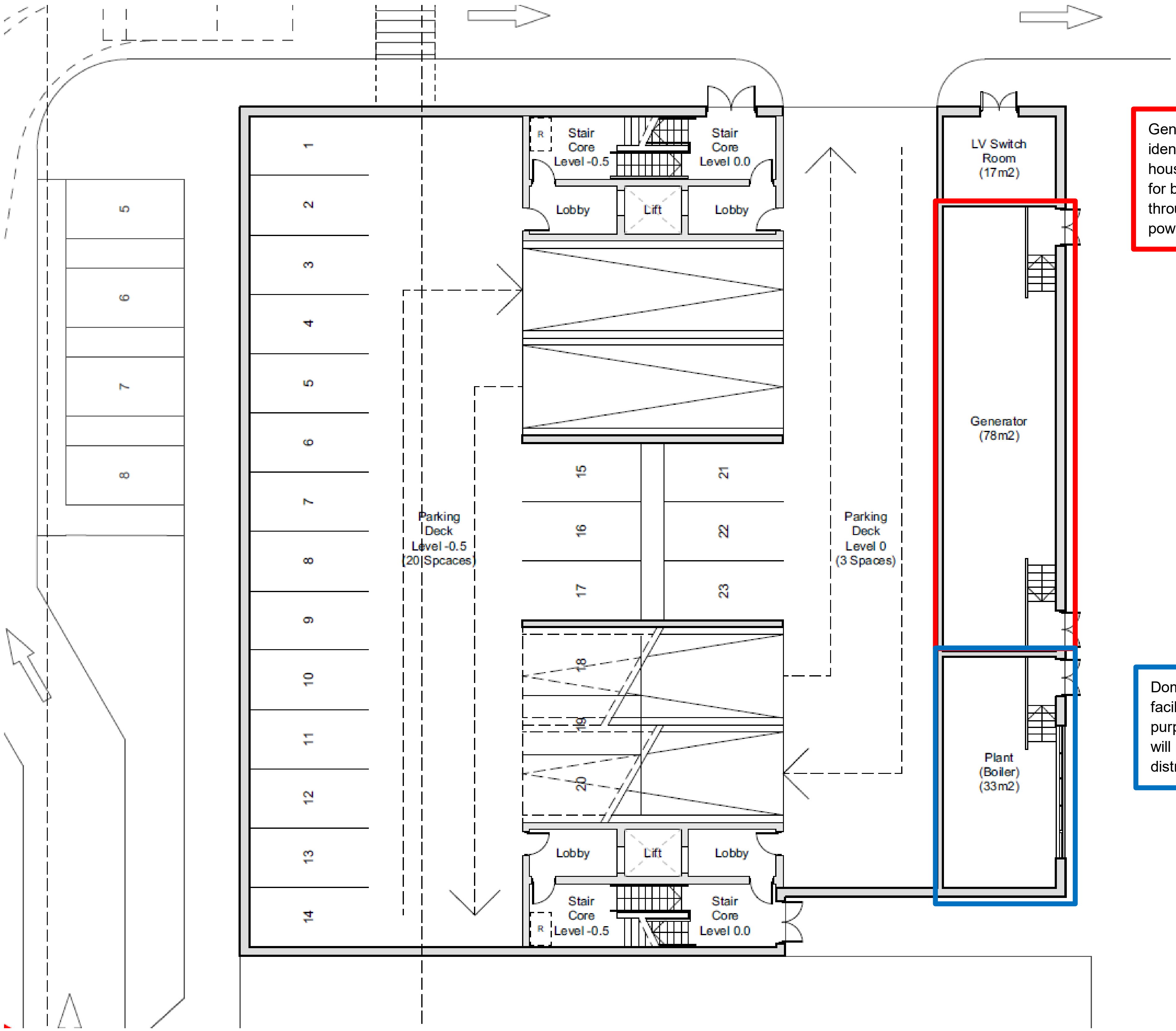
2. Next Steps

The next steps are outlined as:

1. Obtain or develop a schematic of the building heating circuit such that the required extent and scope of works can be determined.
2. Obtain or develop a heat loss model for the building including refurbishments to determine the required heating.
3. Monitor internal temperatures throughout a winter period.
4. Produce a scoping document to set out the works required and tender to contractors, including water sampling, pump modification, boiler and control adjustments, and the rebalancing of heating circuits.
5. Undertake system rebalancing. This can be carried out prior to connection to district heating network if the current primary plant (i.e. boilers) has the ability to do so. Alternatively, this will be carried out when the district heating network is ready for connection.

Appendix E – Energy Centre Location Opportunities

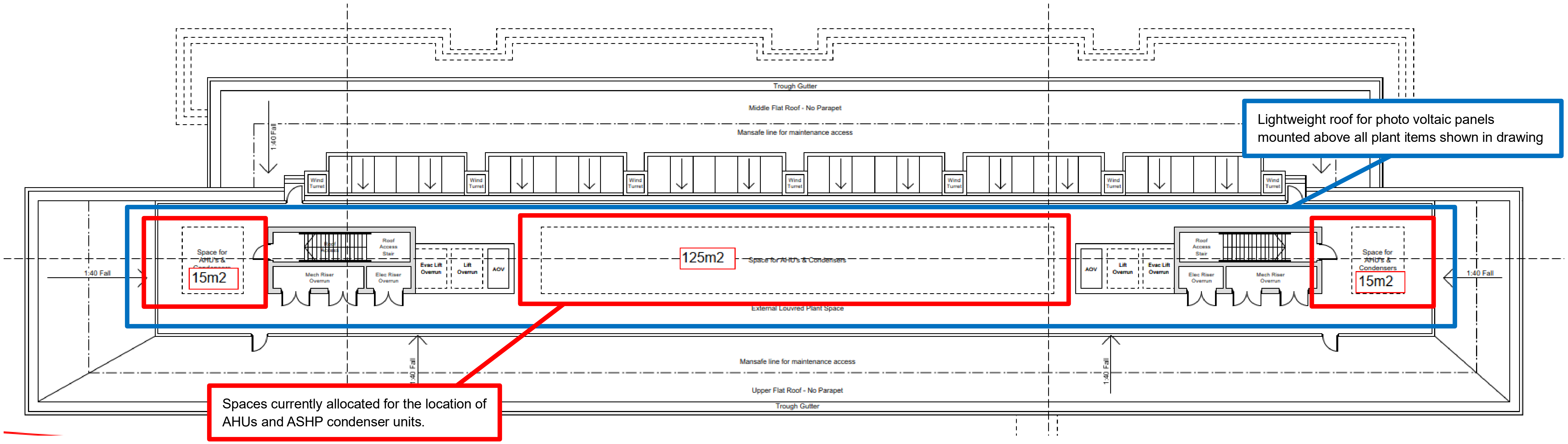
E.1 WICC Site – Multi Story Car Park Plant Area



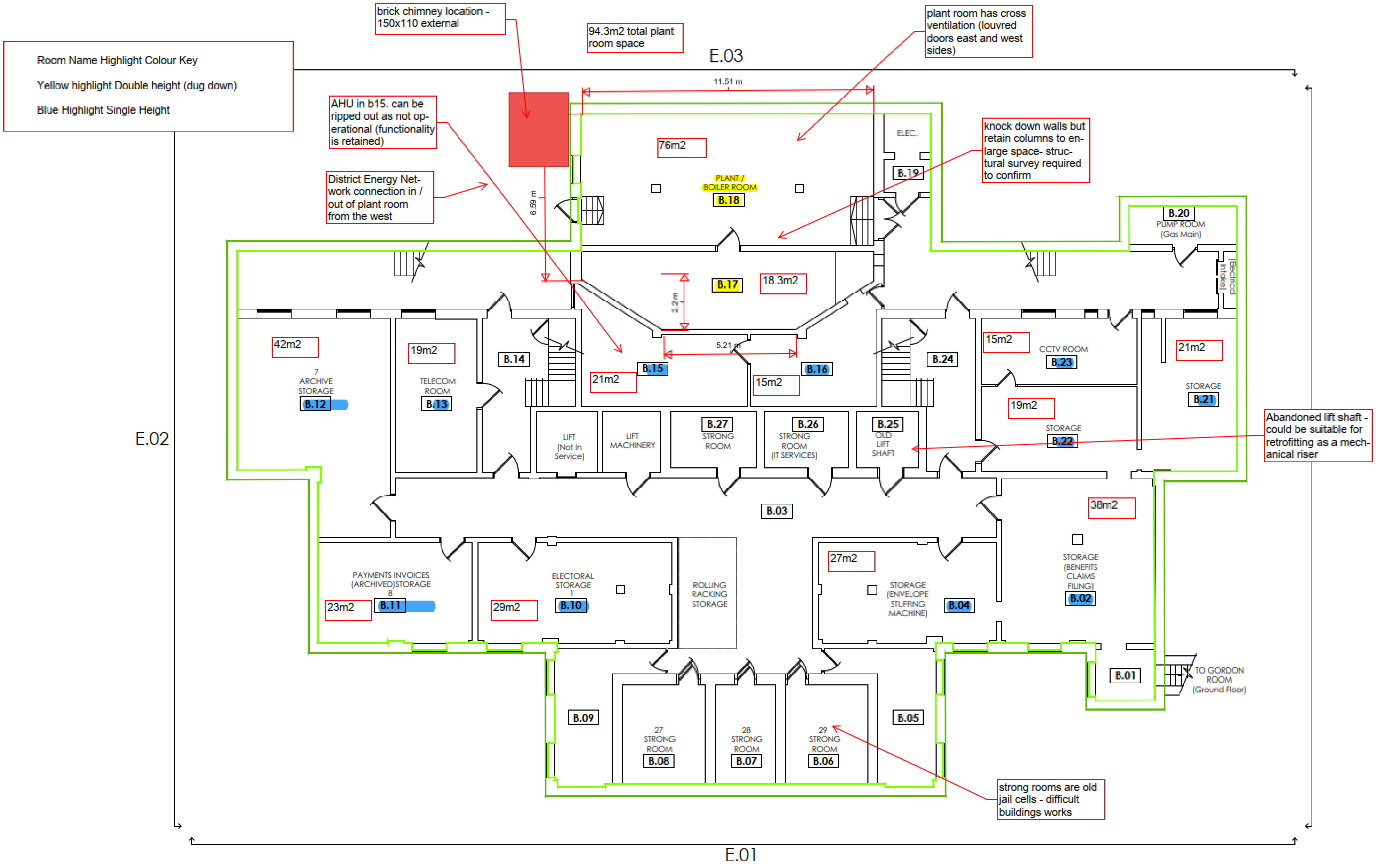
Generator room within the MSCP facility identified as being suitable for the purposes of housing DEN equipment, should the requirement for backup diesel generators be replaced through a secondary connection to the UKPN power grid.

Domestic hot water boiler room within the MSCP facility identified as being suitable for the purposes of housing DEN equipment, as plant will no longer be required if connection to a district heating network is provided.

E.2 WICC Site – Clinic Roof Space



E.3 Town Hall / Assembly Hall Plant Room – Site Survey Notes



Appendix F – Generation Plant Details

The below table details the high-level suitability analysis of generational plant items undertaken prior to the development of the energy masterplans analysed within the modelling portion of this study.

Energy generation technology	Core scheme	Extended scheme	Rationale
Closed loop ground source heat pump - boreholes	✓	✓	Development of WICC site offers opportunity to drill the required number boreholes to provide the peak heating demands for the Civic Quarter site. Ground recharge is required through the capturing of waste heat from VRV cooling units, such as those cooling the server rooms in the Town Hall, Library, Law Courts and Museum. Space restrictions within the WICC development area limit the upper capacity of ~200kW (see overleaf for full details).
Open loop ground source heat pump	✓	✓	Civic quarter site is situated above chalk bedrock, providing a suitable aquifer for extraction of ground water
Sewer source heat pump	✓*	✓	1.5m diameter sewer located 450m from Civic Quarter, adjacent to Union Place development site
Air source heat pump	✓	✓	Care centre design in WICC site includes flat roof, offering opportunity to install air source heat pumps
Marine source heat pump	X	✓	Civic quarter site is 600m from shoreline, therefore solution is not economically attractive for Core scheme, but could be for an extended scheme if developed toward Worthing town centre
Gas boiler	✓	✓	Gas supply possible
Electric boiler	✓	✓	Power supply possible
Biomass boiler	X	✓	No on-site storage of fuel possible due to spatial constraints
Combined heat and power (gas)	✓	✓	Gas supply possible. Small private wire network already in operation.
Combined heat and power (biofuel)	X	✓	No on-site storage of fuel possible due to spatial constraints

Table F-1: Heating solutions viability assessment for use in the Civic Quarter

The technologies identified as being suitable for the Core Scheme (i.e. serving the Civic Quarter) are all highlighted within Section 4 of this report.

Of the identified suitable low and zero carbon technologies, 4 are heat pump systems. The generational efficiency of each system is variable depending on the ambient temperatures of the energy source, as shown in Figure F-1 below:

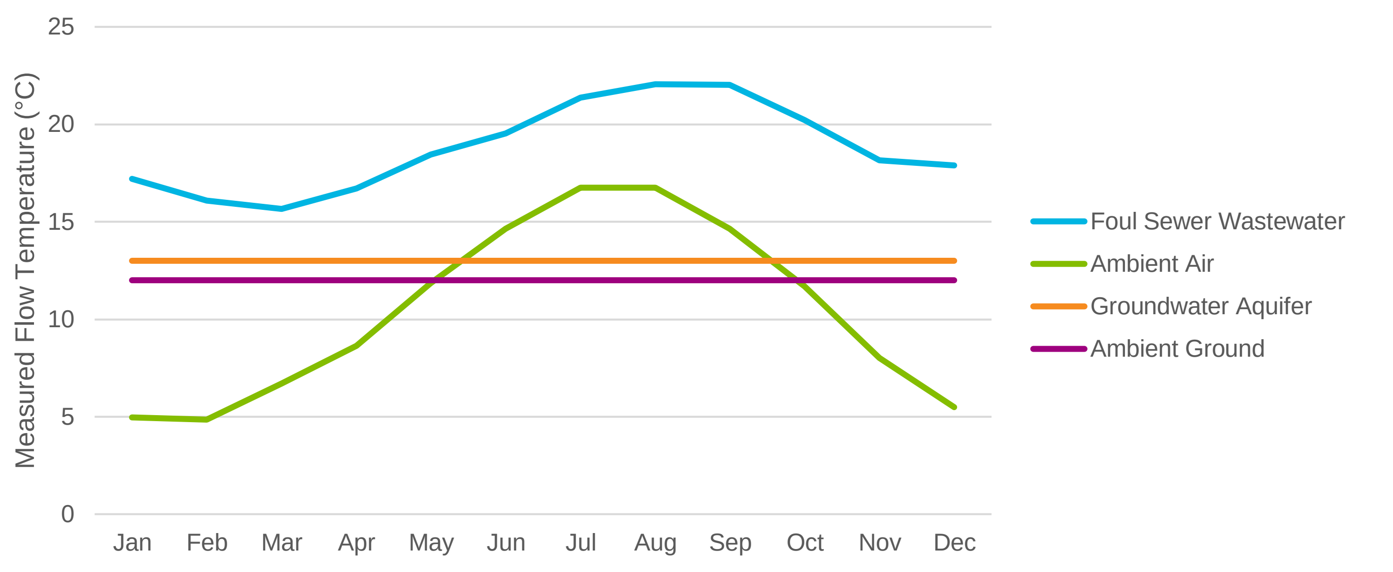


Figure F-1: Monthly average temperatures for different heat pump sources

Figure F-1 shows that the temperature of the air and foul sewer are subject to weather conditions, whereas those of the groundwater aquifer and ambient ground are far more stable across the seasons. These temperature profiles correlate to the efficiencies detailed in Table F-2 below.

Energy generation technology	Fuel Type	Average annual efficiency when supplying heat to an 80°C flow temp. network	Average annual efficiency when supplying heat to a 60°C flow temp. network
Closed loop ground source heat pump - boreholes	Electricity	2.9	3.6
Open loop ground source heat pump	Electricity	2.9	3.7
Sewer source heat pump	Electricity	3.1	4.1
Air source heat pump	Electricity	1.8 – 2.4	2.5 – 3.1
Gas boiler	Gas	86 - 96%	86 - 96%
Electric boiler	Electricity	100%	100%
Combined heat and power (gas)	Gas	78 – 86%	78 – 86%

Table F-2: Generational efficiencies of the viable Civic Quarter heating solutions

Table F-2 show that the efficiencies of the heat pump technologies are related to the output temperatures of the system, whereas the boiler and CHP solutions are not as they are typically designed to produce heat at 85°C or above.

F.1 Closed Loop Ground Source Heat Pumps, Borehole Type

Summary

A CL-GSHP system collects shallow ground energy held within the soil. The system incorporates an array of boreholes, typically 150m deep, within which plastic pipes are installed. To extract the energy, a working fluid mixture of water and glycol is pumped through these plastic pipes, which is heated or cooled (as required) as it is pumped through the buried pipework.

To ascertain the viability of a CL-GSHP system to meet the heating requirements of the Civic Quarter site, a desktop feasibility analysis has been undertaken. This analysis is summarised below.

Introduction to Desktop Feasibility Analysis

A district heating network is proposed for the cluster of buildings around Worthing town hall. This part of the work covers an analysis of a potential ground source heating system in an area of the site.

This analysis considers three different scenarios - with either 145, 76 or 30 boreholes. The outcome of the analysis shall determine the technical viability of such a solution within the Civic Quarter site.

Energy Loads

Heating and cooling loads were provided by the wider team.

The images below show the yearly heating and cooling loads broken down by maximum and average.

Maximum Power (kW)

Heating

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Midnight	259	248	227	268	163	113	116	115	132	347	302	355	355
01:00	363	314	283	233	170	105	95	100	106	308	376	496	496
02:00	377	312	340	249	199	107	97	107	108	327	448	447	448
03:00	489	430	442	372	242	102	101	100	116	266	424	499	499
04:00	552	468	477	521	373	202	239	226	216	448	428	621	621
05:00	808	656	570	541	436	220	146	155	191	539	758	833	833
06:00	820	789	727	573	423	224	169	136	178	391	570	770	820
07:00	795	712	775	638	467	214	159	155	200	446	912	984	984
08:00	789	752	727	617	474	205	122	134	207	463	803	891	891
09:00	827	767	767	551	422	205	146	128	197	435	747	868	868
10:00	792	761	822	516	383	178	131	129	168	454	705	824	824
11:00	764	698	727	501	345	187	138	122	156	408	668	796	796
Noon	814	683	700	545	309	166	126	129	141	412	625	784	814
13:00	705	653	647	469	307	215	118	128	197	355	633	772	772
14:00	696	645	652	456	304	174	121	124	190	360	619	752	752
15:00	805	641	695	412	297	157	124	117	152	344	626	756	805
16:00	718	633	673	391	276	255	109	120	139	333	633	746	746
17:00	700	603	610	412	282	187	107	119	143	311	593	717	717
18:00	601	554	566	319	244	206	102	135	131	328	533	685	685
19:00	440	410	419	214	205	121	95	102	123	338	327	458	458
20:00	308	289	329	223	186	115	103	116	125	304	254	430	430
21:00	292	288	285	193	161	111	100	103	106	280	255	430	430
22:00	258	255	271	180	161	105	94	118	110	225	391	383	391
23:00	245	212	237	178	164	108	132	108	104	301	297	359	359
Total	827	789	822	638	474	255	239	226	216	539	912	984	984

Cooling

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Midnight	0	1	1	1	57	52	98	69	72	11	1	1	98
01:00	0	1	1	1	39	41	84	50	47	9	1	1	84
02:00	0	1	1	1	24	40	62	41	43	7	1	1	62
03:00	0	1	1	1	20	36	58	33	41	3	1	1	58
04:00	0	1	1	1	8	30	47	26	45	2	1	1	47
05:00	0	1	1	1	4	27	58	24	44	1	1	1	58
06:00	0	1	1	1	19	68	102	25	65	1	1	1	102
07:00	0	1	1	1	68	150	247	96	92	1	1	1	247
08:00	0	1	1	1	142	300	380	252	144	24	1	1	380
09:00	0	1	1	1	220	432	476	405	176	40	1	1	476
10:00	0	1	1	1	309	476	476	476	219	46	1	1	476
11:00	0	1	1	5	413	476	476	476	289	84	1	1	476
Noon	0	1	65	50	476	476	476	476	306	110	1	1	476
13:00	0	4	122	62	476	476	476	476	359	139	1	1	476
14:00	0	5	174	94	476	476	476	476	417	152	20	1	476
15:00	0	2	120	104	476	476	476	476	437	171	27	1	476
16:00	0	1	90	110	476	476	476	476	476	153	11	1	476
17:00	0	1	59	117	476	476	476	476	476	156	5	1	476
18:00	0	1	24	47	476	476	476	476	472	135	2	1	476
19:00	0	1	10	19	449	476	476	476	455	149	1	1	476
20:00	0	1	4	8	397	476	476	476	422	102	1	1	476
21:00	0	1	2	4	246	329	350	316	279	62	1	1	350
22:00	0	1	1	2	133	181	209	175	151	33	1	1	209
23:00	0	1	1	1	79	95	131	99	97	17	1	1	131
Total	0	5	174	117	476	476	476	476	476	171	27	1	476

Average Power(kW)

Heating

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Midnight	200	193	172	158	108	90	93	94	94	152	178	223	146
01:00	198	203	183	158	105	82	82	82	87	133	200	255	147
02:00	249	229	200	165	103	83	84	85	86	137	202	257	157
03:00	286	268	237	202	123	84	84	83	88	134	227	296	176
04:00	369	331	290	315	172	122	165	163	156	298	250	359	249
05:00	580	474	423	371	218	130	94	103	108	271	527	619	326
06:00	673	652	551	360	221	125	101	101	117	260	436	527	344
07:00	657	635	603	455	251	154	115	121	133	296	680	708	401
08:00	702	676	615	459	247	140	101	104	137	345	651	696	406
09:00	698	682	602	433	230	137	101	106	137	327	638	703	399
10:00	671	655	578	395	202	128	98	100	120	307	600	668	377
11:00	643	629	549	374	197	127	96	95	114	290	569	651	361
Noon	632	606	505	355	184	118	94	97	111	275	537	628	345
13:00	610	584	477	338	177	122	93	95	110	259	518	606	332
14:00	592	567	470	327	168	116	92	93	112	253	494	592	323
15:00	596	563	454	304	163	109	86	88	105	237	488	592	315
16:00	589	551	433	296	162	111	87	93	102	230	487	596	311
17:00	532	516	420	300	161	107	83	92	111	224	472	571	299
18:00	479	465	395	260	158	109	79	90	96	177	415	481	267
19:00	335	344	298	176	115	88	78	83	93	161	259	322	196
20:00	248	247	227	184	114	85	82	86	90	159	209	267	167
21:00	238	243	217	164	101	87	80	82	87	149	210	267	160
22:00	212	213	192	157	100	77	79	83	84	137	194	240	147
23:00	188	188	174	152	97	82	82	82	83	137	182	224	139
Total	466	446	386	286	162	109	93	96	107	223	401	473	271

Cooling

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Midnight	0	1	1	1	5	9	30	19	9	1	1	0	6
01:00	0	1	1	1	3	6	22	12	7	1	1	0	5
02:00	0	1	1	1	2	5	16	8	7	1	1	0	3
03:00	0	1	1	1	2	4	13	6	6	1	1	0	3
04:00	0	1	1	1	1	3	10	4	5	1	1	0	2
05:00	0	1	1	1	1	3	11	3	4	1	1	0	2
06:00	0	1	1	1	2	6	16	5	5	1	1	0	3
07:00	0	1	1	1	4	13	29	10	6	1	1	0	5
08:00	0	1	1	1	9	30	68	29	10	1	1	0	13
09:00	0	1	1	1	15	55	115	65	19	2	1	0	23
10:00	0	1	1	1	22	81	165	102	38	3	1	0	34
11:00	0	1	1	1	42	114	216	155	68	5	1	0	50
Noon	0	1	3	4	62	142	245	194	95	9	1	0	63
13:00	0	1	5	7	76	164	285	226	106	14	1	0	74
14:00	0	1	7	11	87	182	294	251	121	18	1	0	81
15:00	0	1	6	14	89	188	312	268	122	18	2	0	85
16:00	0	1	4	11	85	190	305	271	118	15	1	0	83
17:00	0	1	3	9	78	183	298	256	107	12	1	0	79
18:00	0	1	1	4	66	173	288	236	88	10	1	0	72
19:00	0	1	1	2	51	151	275	203	67	9	1	0	63
20:00	0	1	1	1	37	114	213	162	50	7	1	0	49
21:00	0	1	1	1	22	63	132	96	31	4	1	0	29
22:00	0	1	1	1	13	32	75	52	18	3	1	0	16
23:00	0	1	1	1	7	17	47	29	12	2	1	0	10
Total	0	1	2	3	33	80	145	111	47	6	1	0	36

Figure F1-1: Annual heating and cooling load heat map

First looking at the heating loads, it can see there is a relatively small requirement for heating in the summer. This points to the buildings being served being relatively poorly insulated, and the domestic hot water (DHW) demand being relatively low. The early morning heat up predicted is relatively small compared to a typical modern building. Average load over the year is 271kW with peak power of 964kW.

Cooling loads are concentrated in the summer, with almost no cooling away from these times. The peak cooling power requirement is relatively high, with large periods of the summer having the potential for 476 kW of cooling requirement. The average cooling load is only 36kW.

The total heating and cooling loads are very imbalanced. For a closed loop GSHP array, It is fine to be imbalanced over a year, but after a few decades this will lead to a reduction in the average ground temperatures. If there is a small data centres on site that can be plugged into the system, it will make a significantly positive difference – only around 130kW of data centre (8m x 8m) is needed.

Ground Conditions

An examination of the bed rock shows Seaford Chalk covers the majority of the site.

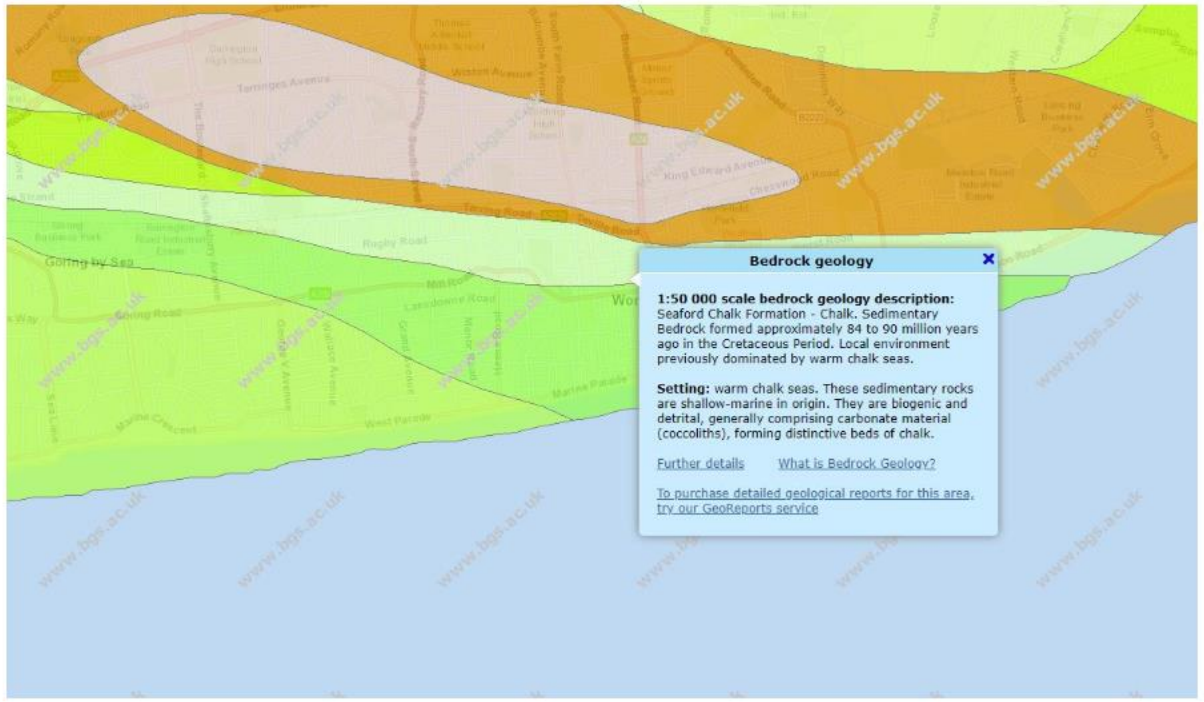
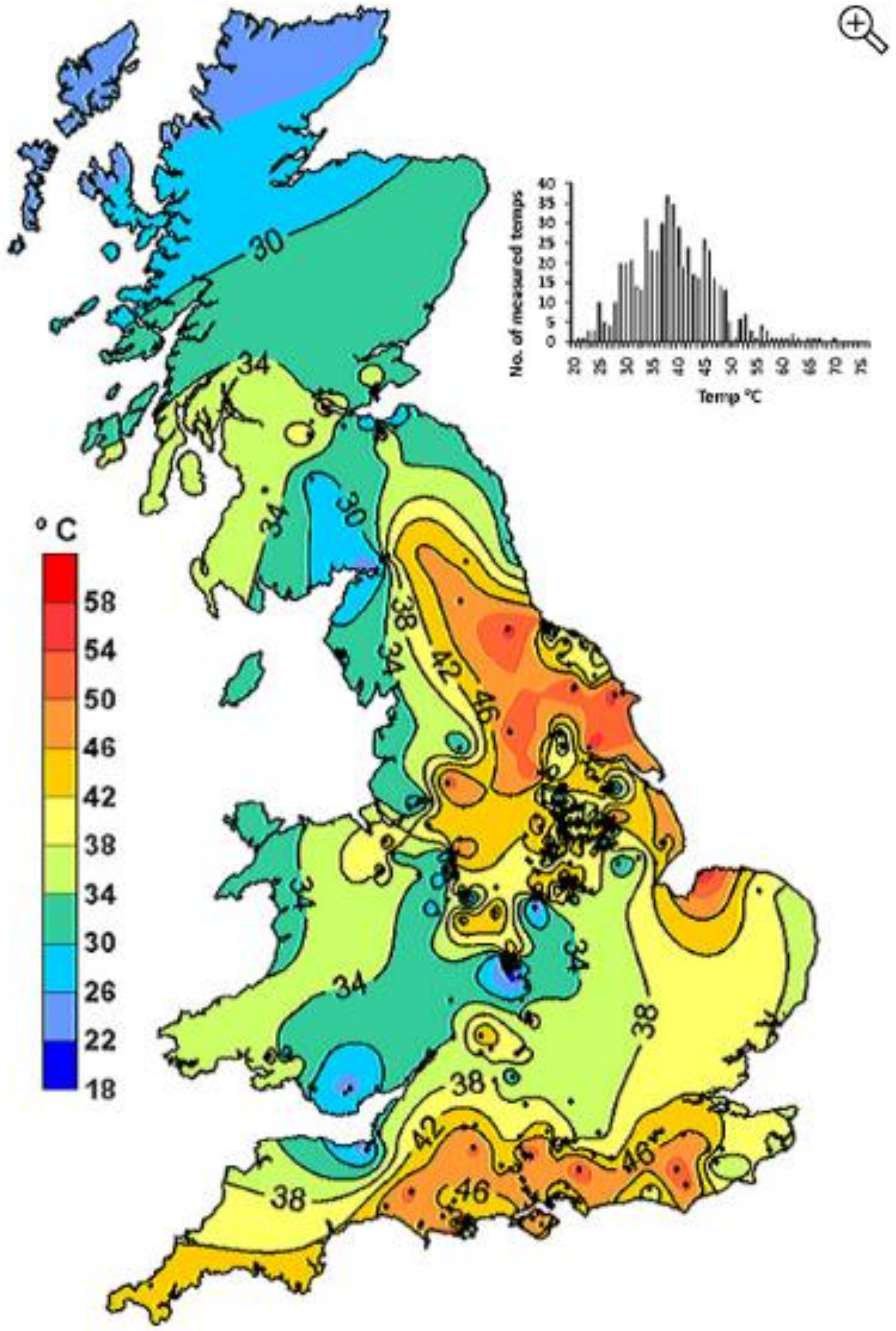


Figure F1-2: Ground conditions in and around Worthing

Deep Heat

Figure F3-1 below shows the temperatures 1000m below ground level. Worthing sits in a slightly geothermally warmer area of the country. To remain conservative, it will be assumed that the entire undisturbed ground temperature is at 14°C, compared to the potential 18°C at 150m deep that this image suggests.

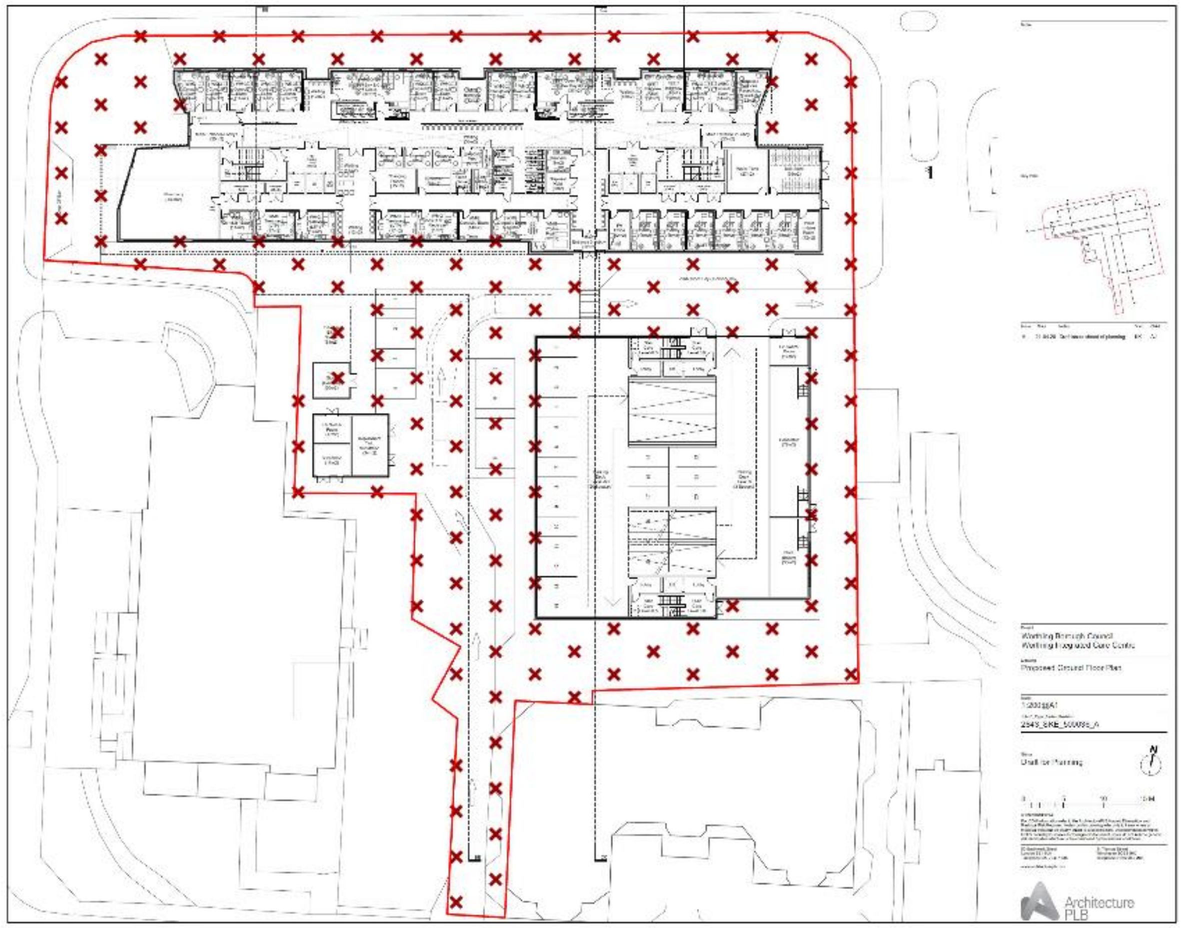


The temperature depth slice at a 1000 m below ground level.

Figure F1-3: Deep heat temperatures in the UK

145- Pile case

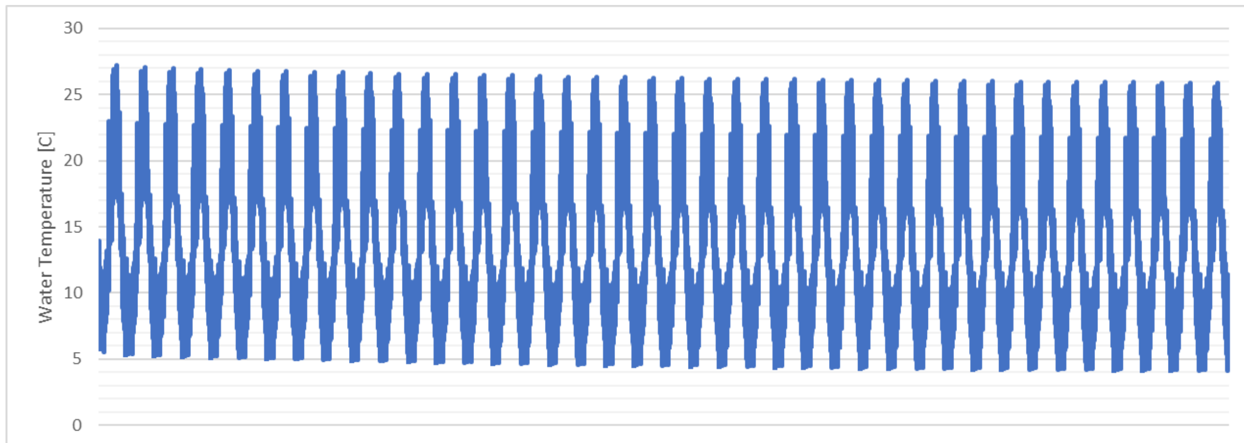
To squeeze as many ground source piles onto site, a genetic solver was applied to align the grid pattern. Piles have been placed in areas which are both within the red line boundaries and spaced by 5.7m. Space has been found for 145 piles, 150m long.



A simulation will the large imbalanced heating load spread over the piles showed a rapid freezing of the ground. This will cause ground movement and possibly structural damage and is unacceptable.

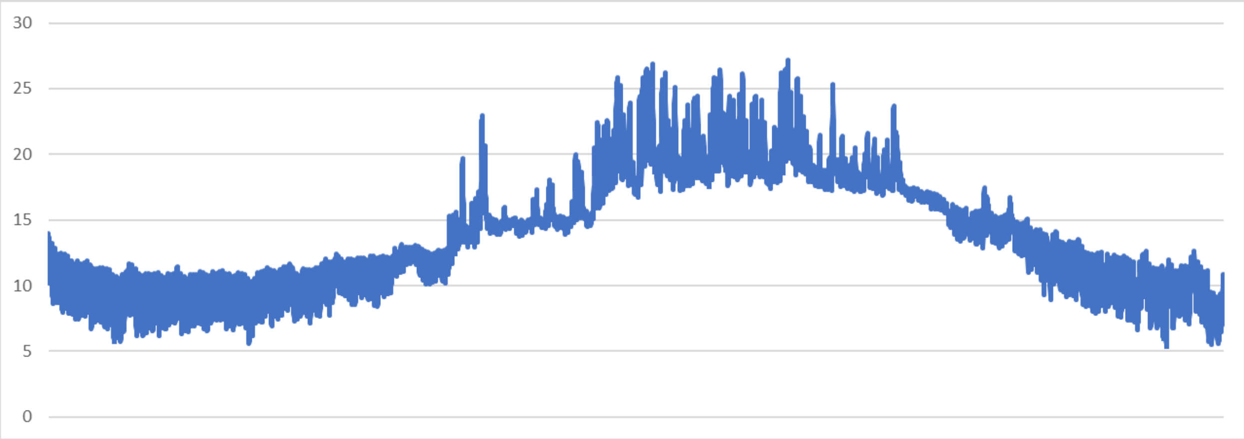
This simulation assumes a 150kW heat load is found from somewhere applied on average over the year. This could be a data centre as previously mentioned, a small sewer source heat pump, or an air source heat pump that is able to run when most efficient – during the warmest part of the year.

With this load in place, the following average water loop temperatures are predicted within the piles:



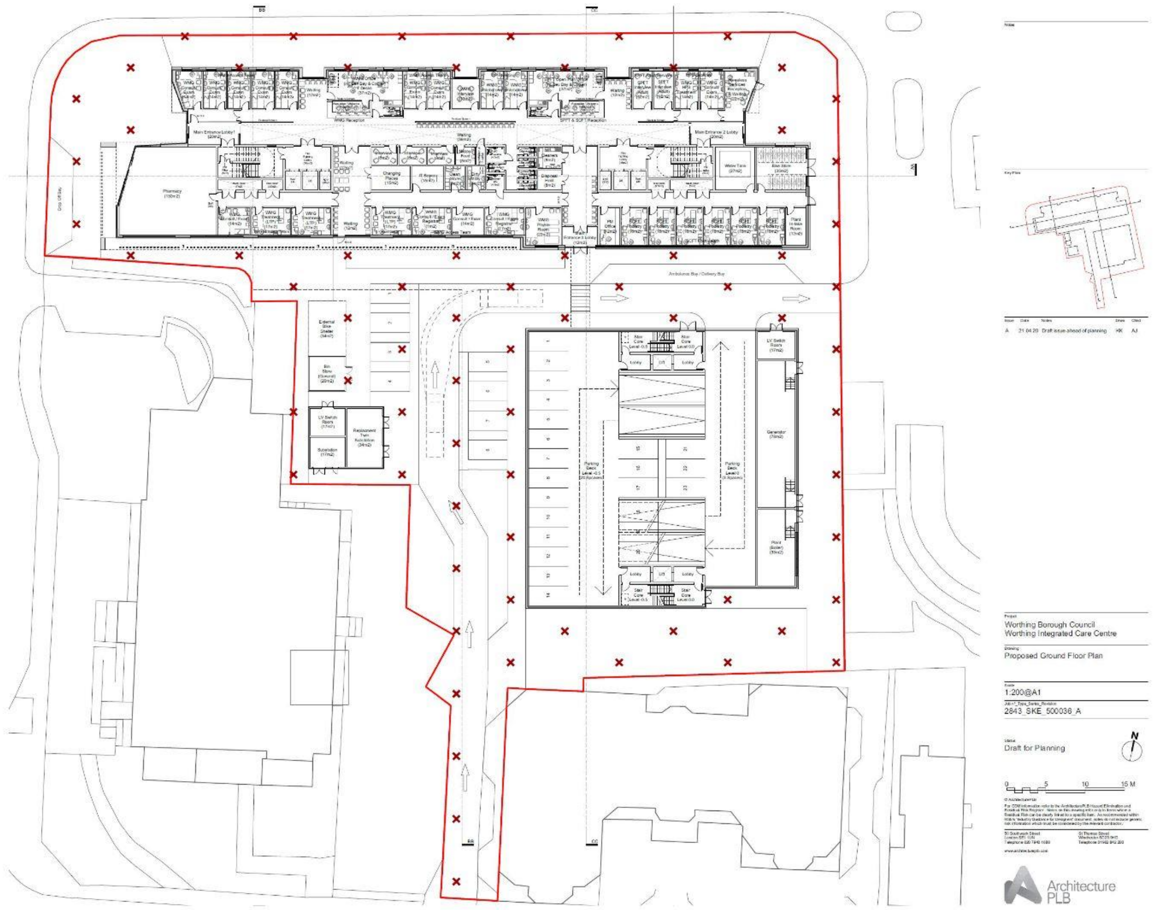
Each low point is a winter heating season and each high point a peak summer. It can be seen that the simulation has been performed over multiple decades.

The image below shows the same data, but for a single year. It can be seen (as expected) that the large, rare cooing spikes are well separated, and the relatively more consistent heating periods are smoother.



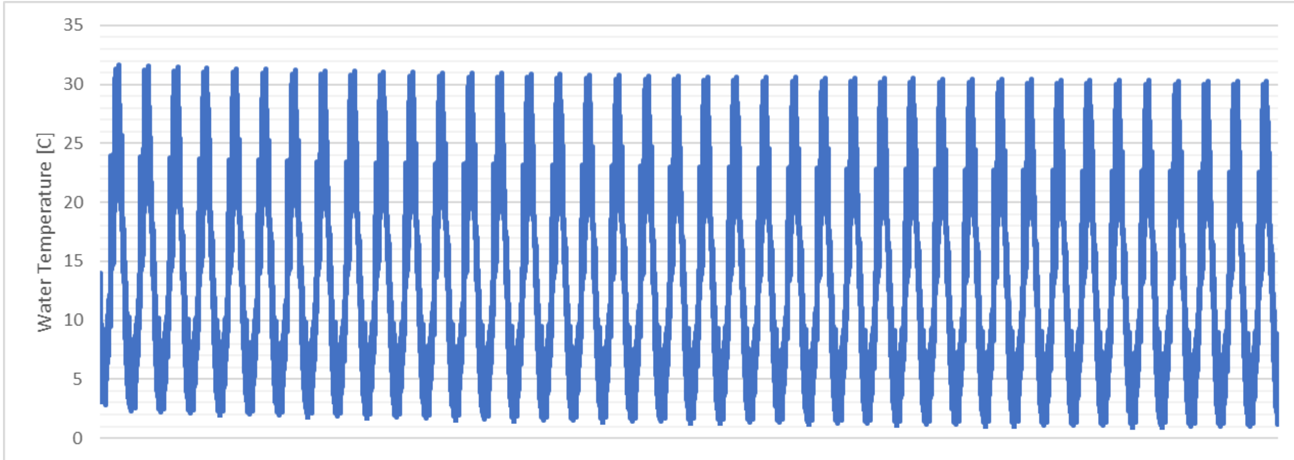
76 Pile Case

To reduce the costs associated with the number of boreholes, a second case was tested. This had the reduced number of piles shown in the graphic below:

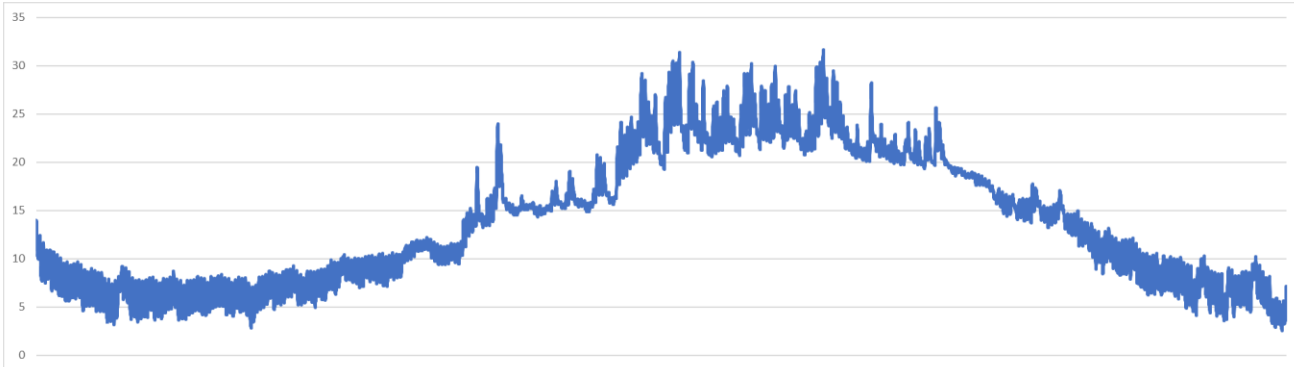


When this was simulated, it was found that overheating of the ground was occurring at short time scales. To reduce these peaks, and to provide better thermal contact with the ground, a 50m3 buffer tank was added to the hot side of the system, and the bore holes were altered to be double, rather than single U-tube design.

With these changes, the water temperatures below were found over the simulated decades.



And again, zooming in on a single year



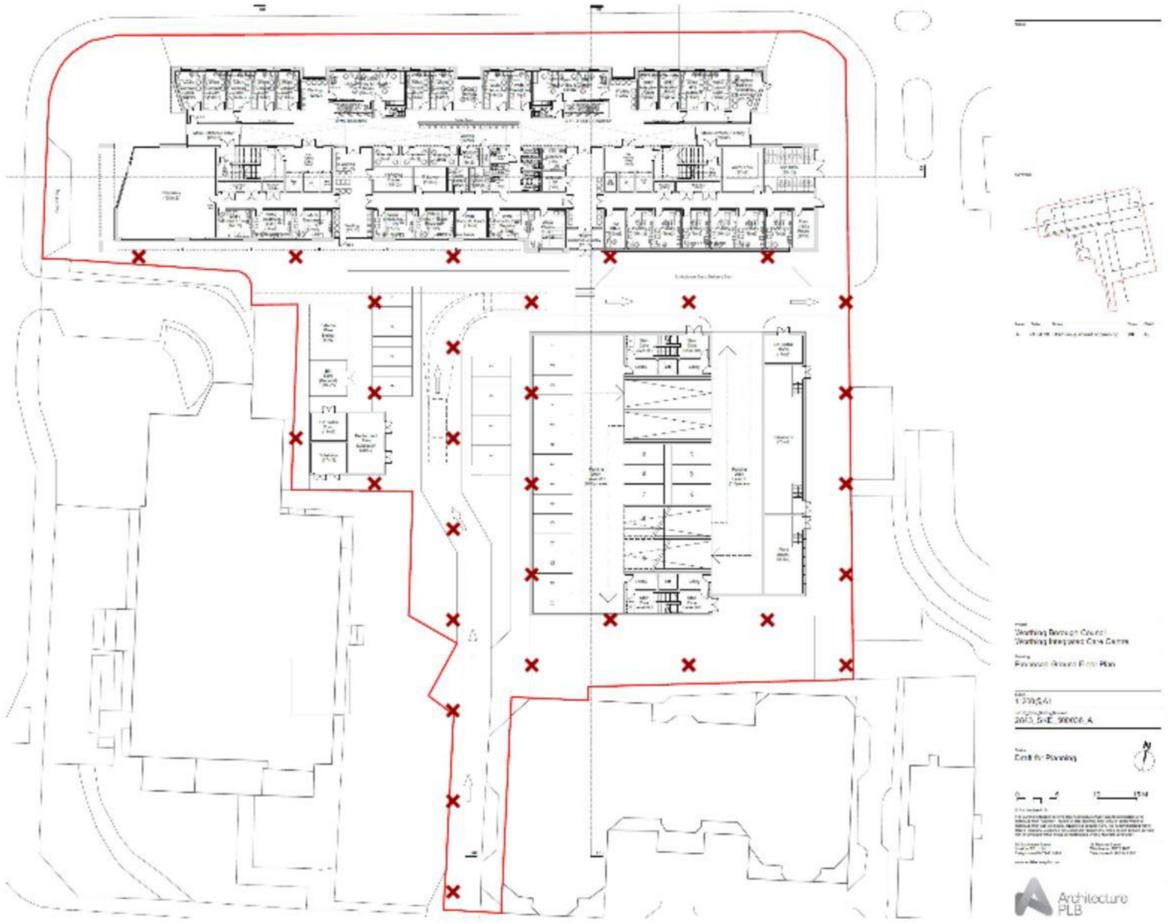
In this scenario, the energy loads are well suited to balancing annual variation but are unable to cope with the decades long heating dominance seen in these loads.

A 150kW balancing source of waste heat is recommended for a full CL-GSHP solution to serve the entire Civic Quarter site. Cooling systems used within server rooms are ideal to provide this type of base load heating.

12.4 30 Pile Case

To reduce costs again a third case was tested. This had the reduced number of piles shown in the graphic below:

Here the spacing has been increased to 11.3m separation.



This case also has the 50m3 buffer tank, and the double U-tube design.

With this reduced number of piles there is insufficient contact between the soil and the water to properly buffer the yearly swing in heating demand. To mitigate this an air source heat pump / dry air cooler is set to run continuously providing heat in the winter, and a little cooling in the summer. While this has been modelled as continuous, it is likely this can be variable. This would help by allowing the air source heat pump to not run during the coldest evenings where de-icing is usually a problem.

Conclusions and Consultation with WICC Development Team

Following on from consultation with the WICC development team, it was deemed that both the 145 and 76 pile cases were undeliverable solutions based on their impact to the current development plans for the site, therefore a CL-GSHP solution would be unable to meet the full heating requirements of the Civic Quarter site.

However, it is deemed that smaller scale, c. 30-pile CL-GSHP case could form a hybrid system in conjunction with ASHP plant, which has been included within the modelling described in Section 7.

F.2 Open Loop Ground Source Heat Pumps

To ascertain the viability of an OL-GSHP system to meet the heating requirements of the Civic Quarter site, a desktop feasibility analysis has been undertaken. This analysis is summarised below.

Summary

OL-GSHP schemes typically involve abstraction of groundwater from one or more boreholes which is then passed through a heat exchanger where heat is either extracted or added to the water, depending on whether the scheme is in a heating or cooling mode, and then discharged through another borehole or boreholes to the same aquifer as the abstracted water.

The two main constraints on any OL- GSHP schemes are the availability of sustainable abstraction rates from the aquifer and the ability to recharge the water back into the same aquifer, especially where the natural groundwater level is shallow with a limited unsaturated zone.

It is also critical that the distance between the abstraction and recharge boreholes is maximised within the site constraints to reduce the risk for the recirculation of recharged water causing a change in the temperature of the abstracted water and thereby reducing the efficiency of the scheme. Whilst the potential for recirculation is dependent on the aquifer characteristics of the boreholes, it is considered that the minimum distance between the abstraction and recharge boreholes should not be less than 100m.

Environment Agency's Position on OL-GSHP Systems

Water abstracted from boreholes for OL-GSHP schemes is considered to be a non-consumptive abstraction by the Environment Agency. As a result, these types of abstractions are normally acceptable to them even where there are resource restrictions in the aquifer. However, prior to licensing, the proposed abstractions are subject to hydrogeological and environmental impact assessment.

If the proposed abstractions rates are greater than $20m^3$/day, an abstraction licence issued by the Environment Agency will be required under the Water Resources Act, 1991. Depending on the discharge rate, an Environmental Permit may also be required for the recharge of the water under the Environmental Permitting Regulations 2010. Both the abstraction licence and the Environmental Permit will include conditions on the volume and quality of the water abstracted and discharged.

The principles by which the Environment Agency will consider applications for new open loop GSHP schemes include:-

- The temperature of the rejected groundwater should not be more than +/- 10ºC of the temperature of the abstracted water;
- The temperature of the rejected groundwater shall not exceed 25ºC;
- There should be an approximate annual balance between the heating and cooling use of the groundwater; and,
- Any new GSHC schemes will need to demonstrate that they have no adverse impacts on existing licensed groundwater abstractions in the area in respect of both groundwater level and quality (temperature).

Objectives of Desktop OL-GSHP Feasibility Study

The objectives of this study are to confirm the geological, hydrogeological and geothermal conditions at the site through a desk-based study. This includes: -

- Review the geological and hydrogeological conditions of the site;
- Review the local groundwater level, quality, flow conditions, flood risk and saline intrusion risk;
- Assess typical borehole yields and the hydraulic characteristics of the aquifer based on the available information; and
- Assess the feasibility of an OL-GSHP scheme.

Information Used and Methodology

The following sources of information have been used in the preparation of this report: -

- Geological Mapping Viewer 'GeoIndex', British Geological Survey (BGS) (accessed May 2020);
- BGS borehole records available at 'GeoIndex' (accessed May 2020);
- Flood Risk Assessment and Drainage Strategy for Proposed Redevelopment Integrated Care Centre and Decked Car Park, Stoke Abbott Road, Worthing Issue 2, Borough Council of Worthing, Cole Easdon Consultants (CEC) (April 2020);
- Preliminary Ground Contamination Risk Assessment Report for Worthing Integrated Care Centre Stoke Abbot Road Worthing West Sussex, Ref R14218, Ashdown investigation Ltd (April 2020);
- Combined Geotechnical and Quantitative Ground Contamination Risk Assessment Report for Worthing Integrated Care Centre, Stoke Abbot Road, Worthing, West Sussex, Ref R14217, Ashdown investigation Ltd (June 2020);
- Hydrogeological Map of the South Downs and Adjacent Parts of the Weald (1:100,000), BGS (1978);
- Hydrogeological Report Series: The Chalk aquifer of the South Downs, Report GD272191/1999, BGS (1999);
- The physical properties of major aquifers in England and Wales' report WD/97/34 BGS (1997); and,

Environmental good practice guide for ground source heating and cooling, report (GEHO0311BTPA-E-E), Environmental Agency, version 2.

Background Information

Site Description

The site is approximately three hectares (ha) in area and is located within the town of Worthing, West Sussex, centred on National Grid Reference TQ 14726 02923. The site is located approximately 600m north of the coast and Sussex Bay. It is bounded by the A259 to the east and south, Stoke Abbott Road to the north and Christchurch Road to the west.

The site is currently occupied by the Worthing Town Hall buildings and a hardstanding car park and it lies on relatively flat ground, varying from approximately 10.3m Above Ordnance Datum (AOD) in the north west adjacent to Christchurch Road to approximately 9.7mAOD in the south by Richmond Road, and 9.4mAOD in the north east adjacent to Stoke Abbott Road.

Proposed Development

The proposed development on the site includes the construction of the Worthing Integrated Care Centre and a decked car park providing 185 spaces. The site is intended to be used as a multipurpose Primary Health Care facility. It is understood that the initial phases of the development will comprise the demolition of the existing buildings.

As part of the sustainability requirements for the proposed development, potential sustainable energy supply options are being considered for the proposed development. One of which is an OL-GSHP Scheme to provide the heating and cooling energy requirement for development. Hence the need for this feasibility assessment.

Assessment of the Geological Conditions

Regional Geology

The regional geology of the area has been interpreted from the BGS 1:625,000 and 1:50,000 scale maps available on the BGS online map viewer 'GeoIndex'.

Regionally, Worthing and the surrounding area are underlain by the White Chalk Subgroup which is up to 200m thick across the area. There are also areas underlain by the London Clay and the Lambeth Group Formations which overlie the Chalk. Superficial deposits of Alluvium, River Terrace, raised Beach and Tidal Flat Deposits overlie the Chalk and the London Clay and Lambeth Group (where present), across the area. These superficial deposits are associated with watercourses and flood plains in the coastal area. Head deposits comprising clay, silt, sand and gravel are also mapped in the northern and eastern parts of the area.

Locally, the site is directly underlain by the River Terrace and Head Deposits overlying the Seaford Chalk and the Lewes Nodular Chalk Formations. The New Pit Chalk Formation outcrops to the south of the site. It is considered that this is associated with the east to west alignment of the Littlehampton Anticline. The New Pit Chalk Formation also outcrops to the west of Worthing town centre.

A north west-south east band of the Lambeth Group and London Clay Formations is mapped as outcropping to the north of the site. This is likely to be associated with the east to west aligned Chichester syncline, which extends westerly to Chichester. A summary of the regional geology, taken from the BGS lexicon, is provided in Table F2-1.

Table F2-1: Summary of regional geology

Period	Group	Strata	Lithology[+]	Thickness[+]
Superficial				
Holocene	-	River Terrace Deposits – Sand and Gravel	Sand and gravel, locally with lenses of silt, clay or peat.	Variable
	-	Alluvium - Clay, Silt, Sand and Peat	Normally soft to firm consolidated, compressible silty clay, but can contain layers of silt, sand, peat and basal gravel. A stronger, desiccated surface zone may be present.	Variable
	-	Raised Beach Deposits - Sand and Gravel	Raised beach deposits are isostatically uplifted beach deposits which crop out in part above high water mark. Shingle, sand, silt and clay; may be bedded or chaotic; beach deposits may be in the form of dunes, sheets or banks.	Variable
Bedrock				
Paleogene	London Clay Formation		The London Clay mainly comprises bioturbated or poorly laminated, blue-grey or grey-brown, slightly calcareous, silty to very silty clay, clayey silt and sometimes silt, with some layers of sandy clay.	Up to 150m
	Lambeth Group		Vertically and laterally variable sequences mainly of clay, some silty or sandy, with some sands and gravels, minor limestones and lignites and occasional sandstone and conglomerate.	Up to 39m
Upper Cretaceous	White Chalk Subgroup	Seaford Chalk Formation	Firm white Chalk with conspicuous semi-continuous nodular and tabular flint seams. Hardgrounds and thin marls are known from the lowest beds.	50 – 80m
		Lewes Nodular Chalk Formation (including the Chalk Rock Member).	Hard to very hard nodular Chalk and hardgrounds with interbedded soft to medium hard Chalks (some grainy) and marls; some griotte Chalks.	35 – 60m
		New Pit Chalk Formation	Generally blocky, white firm to moderately hard Chalk with numerous marl seams. Flint occurs sporadically.	35 – 50m
		Holywell Nodular Chalk Formation	Generally hard nodular Chalk with thin flaser marls and significant proportion of shell debris in part.	25 – 35m

Site Specific Geology

The geology of the site has been interpreted from 1:50,000 scale geological maps available on the BGS online map viewer 'GeoIndex', from available BGS borehole logs in the vicinity of the site and the logs from three boreholes and five window samples drilled on the site in May 2020 as part of the proposed development.

The logs from the boreholes and window samples drilled in May 2020 indicate that the site is underlain by up to 1.7m of Made Ground overlying up to 9m of superficial River Terrace Deposits comprising interbedded layers of silty, sandy clays and silty sandy fine to coarse gravels with flint. The Chalk bedrock described as off white and cream was proved in the three boreholes at depths of 9m to 10m below ground level to the base of the investigation boreholes (20m). The borehole location plan is provided below:

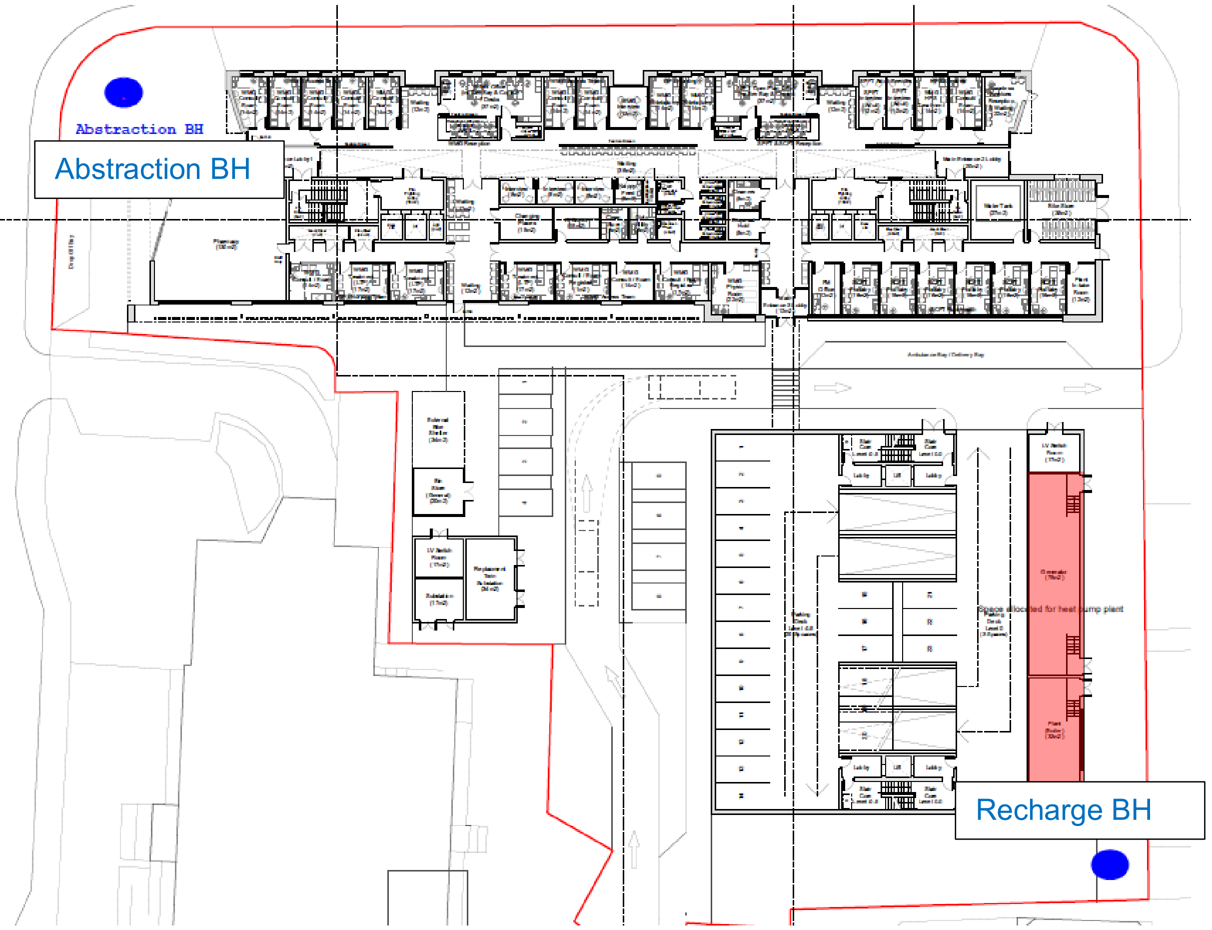


Figure F2-1: Borehole location plan

Three shallow boreholes from BGS records shown at a single location (TQ105SW126) in the central part of the site were drilled to depths of between 10m and 15m. The BGS logs indicate a layer of made ground up to 1.5m thick, overlying superficial deposits to depths of approximately 6.4m and 9m. The superficial deposits comprise clays, stones, sands, gravels and cobbles. A weathered Chalk layer is described in two of the logs from 6.4m to a depth of approximately 10.3m. No additional site-specific information on the nature of Chalk was available from the logs.

BGS borehole TQ10SW152, approximately 400m west of the site drilled in 1979, recorded superficial deposits comprising sands and gravels to a depth of approximately 8m. These are underlain by a weathered / weak Chalk zone to a depth of approximately 36m. The Chalk at this location was proved to a depth of approximately 200m and was described as hard Chalk with flints between 36m and 111m, blue marly Chalk from 111m to 138m and hard marly Chalk from 138m to the base of the hole (200m).

The log for BGS borehole TQ10SE214, approximately 180m north east of the site, recorded the Chalk rockhead at a deeper level 41m below datum, beneath a cover of London Clay and Lambeth Group.

Summary

Based on the review of the available geological information for the area, it is considered that the site is underlain by a thin layer of made ground over up to 9m of River Terrace Deposits overlying the Seaford Chalk aquifer. The inferred surface of the Chalk is between approximately 6m and 10m bgl and the Chalk is up to 200m thick in the area.

Hydrogeological Conditions

Aquifer Classification and Properties

The Chalk bedrock (Seaford Chalk and Lewes Nodular Chalk) underlying the site is classified as a Principal aquifer. The River Terrace Deposits are designated as Secondary A, the Alluvium as Secondary B and the Head Deposits as Secondary (Undifferentiated) aquifers respectively.

The Chalk aquifer is the primary water-bearing unit below the site. The Chalk typically has a low intergranular permeability, but a high secondary permeability imparted by the presence of fractures and fissures. The bulk of groundwater flow in the Chalk is therefore within the fracture system, which encourages rapid groundwater flow.

The River Terrace Deposits are likely to have a high intergranular permeability which enables groundwater flow. Where these deposits directly overlie the Chalk, they are likely to be in hydraulic continuity. Where cohesive Made Ground, Head Deposits or Alluvium or clayey bands within the River Terrace Deposits are present, these strata will have a variable / low permeability which may support minor perched groundwater. The Chalk bedrock underlying the site is unconfined due to the absence of the low permeability London Clay and the Lambeth Group cover.

The Chichester syncline to the north of the site is likely to form a barrier to groundwater movement, restricting southward-flowing groundwater and diverting it to the east. However, this barrier is understood to be breached in places. It is likely that the Palaeogene Formations (the London Clay and the Lambeth Group) infilling the syncline in this area provides a protective cover and confines the Chalk groundwater.

There is no site-specific data available for the hydraulic properties of the Chalk aquifer at the site. However, limited details on groundwater pumping tests completed on historical boreholes in the vicinity of the site are available in the BGS archive records.

A pumping test carried out on borehole TQ10SW178 installed in the Chalk, located approximately 2km to the west of the site, recorded a drawdown of 0.3m for a pumping rate of 9.5 l/sec (34.35 m^3/hr) during a 10-hour constant rate test in 1963. The rest water level in this borehole at the time of the test was approximately 6.1m below datum.

A second Chalk borehole TQ10SW129 located 2.5 km north west of the site recorded a drawdown of 0.02m for a pumping rate of 0.63 l/sec (2.27 m^3/hr) during a 60-hour pumping test in 1982. The rest water level was approximately 10.2m below datum.

A further borehole also in the Chalk, TQ10SE27 located 1.3km northeast of the site indicated that a drawdown of 9.2m was recorded in the borehole during a five-day constant rate pumping test in 1939 at a rate of 4.2l/sec (15.1m^3/hr). The rest water level was approximately 0.15m below datum.

These observations suggest potentially significant variation in the aquifer response to pumping across the area, potentially due to local variations in the aquifer properties and hydrogeological conditions.

This is consistent with the information on aquifer properties contained in the BGS report WD/97/34 *'The physical properties of major aquifers in England and Wales'*, which indicates the potential for significantly variable transmissivity values in the Chalk across the area, ranging from 16 m^2/d to 9500 m^2/d with a median of 440 m^2/d.

Groundwater Abstractions

Regionally, the Chalk is an important aquifer and is used for both private and public water supply abstractions. The site does not lie within any Source Protection Zone (SPZ) for public groundwater supplies. The nearest SPZ 2 (Outer Protection Zone) is approximately 1.3 km to the north east of the site. An inner SPZ 1 (Inner Protection Zone) is shown approximately 1.5km to the north east. It is likely that the SPZ is associated with Southern Water Services (SWS) Northbrook pumping station, approximately 1.8km to the north of the site.

The available Envirocheck records did not identify any licensed water abstractions within one 1km of the site. The nearest private water supply abstraction licence is approximately 1.6km to the north of the site. The BGS records show several boreholes within 1km of the site. It is possible that some of these are in use for private water supply. This will need to be confirmed with the local Environmental Health Officer during future phases of the works if the GSHC progresses.

The BGS 1999 report indicates that SWS operated nine groundwater sources in the Chalk aquifer in Worthing area, designated as the Worthing Chalk Block. The two closest supplies to the site shown on the BGS report are Northbrook and Broadwater, located between 2km – 4km from the site with a combined maximum licensed output of 7Ml/d and 22.5Ml/d respectively.

The site lies within the Littlehampton Anticline East Groundwater body with an overall good (quantitative and chemical) status under the Water Framework Directive (WFD) classification. The CAMS report for the Arun and Western Streams area, which includes the site shows that water resources are available. The document also indicates that new abstraction licences can be considered depending on impacts on other existing abstractors and on surface water.

Groundwater Level and Flow

Regional groundwater levels inferred from the Hydrogeological Map of the South Downs and adjacent parts of the Weald (BGS 1978) indicate that the groundwater level in the Chalk aquifer in the area varied between 10m and 5m AOD with a southerly flow direction towards the coast.

There is limited information on the groundwater level in the Chalk aquifer beneath the site. Groundwater strikes were recorded in the three boreholes drilled in May 2020 on the site at depths of between 4m in the river terrace deposits and a potential further water strike at 9m below ground level, at approximately 0.5m above the Chalk strata (it is not clear from the borehole log whether the deeper water strike is from the Chalk strata). However, the boreholes which were drilled into the Chalk aquifer were not equipped with monitoring facilities, therefore no further groundwater was undertaken from the boreholes. The shallow window sampling probeholes installed at depths of 3m below ground level within the superficial deposits were dry during drilling and in a subsequent monitoring visit.

The nearest Environment Agency monitoring borehole to the site is at Victoria Park, NGR TQ0142000290, approximately 420m to the west and approximately 670m north of the coast. The monthly groundwater level data from this borehole available between June 2007 and early March 2020 provided by the Environment Agency is presented in a hydrograph below.

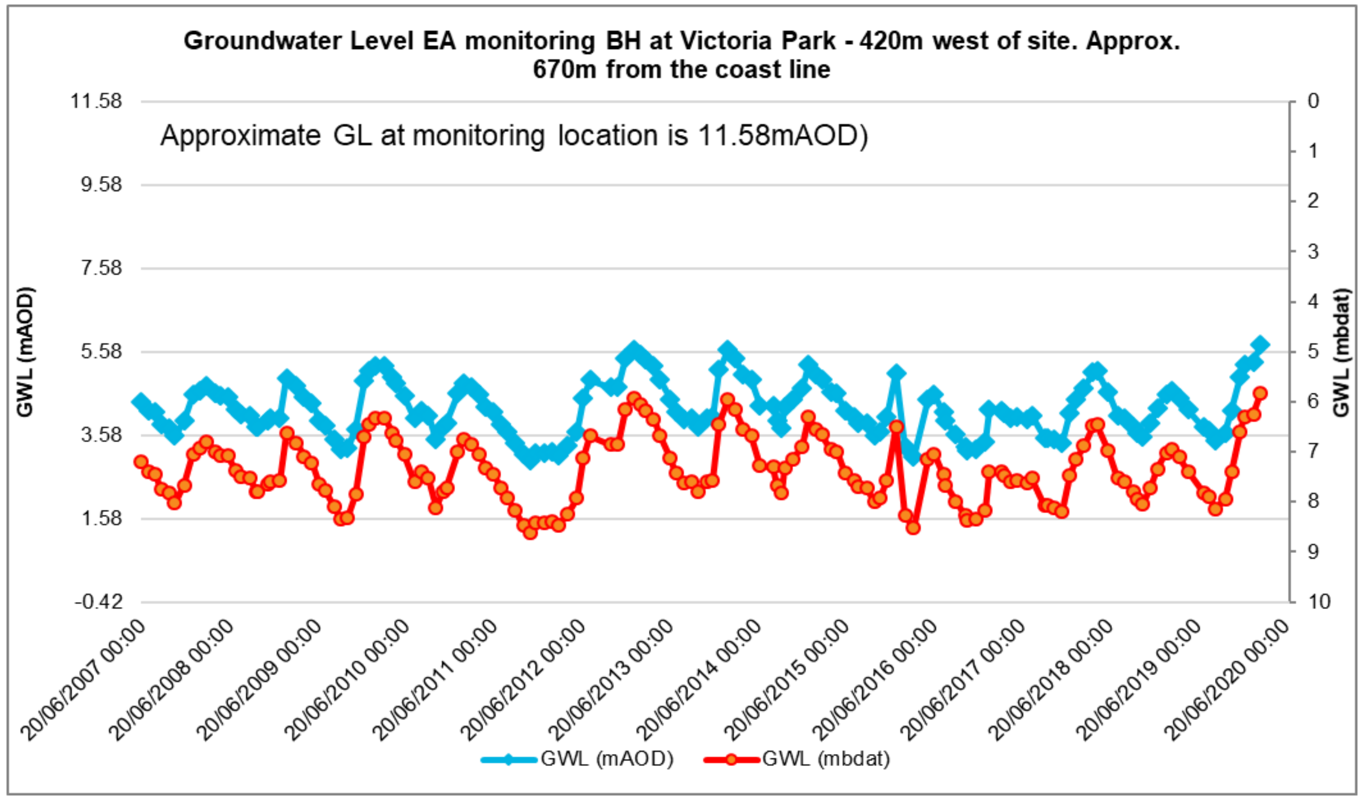


Figure F2-2: Borehole location plan

The data indicates that the groundwater level varies between 2.96m AOD (8.62m below ground level - mbgl) in November 2011 and 5.76m AOD (5.82m bgl) in March 2020, reflecting the wet winter of 2019/2020. This suggests a maximum fluctuation of approximately 2.8m over the monitoring period. The data is only collected on a monthly basis; therefore, it is not possible to clearly determine the potential tidal influence at this monitoring location. Further information on groundwater quality is discussed in Section 4.4.

Records from the BGS logs in the vicinity of the site discussed in Section 4.1 also indicates that the rest water level in the bedrock in the area is generally shallow between approximately 6.1m bgl (3.9m AOD) and 10.2m bgl (-0.2 m AOD).

Groundwater Quality

No site-specific groundwater quality data is available for the site as no samples were collected in the 2020 ground investigation.

Data from the BGS Hydrogeological report of 1999 on the Chalk of the South Downs indicate that to the east of the Worthing Chalk Block, saline intrusion into the Chalk aquifer from both the sea and the tidal River Adur is possible. The report indicates that the Southern Water Supply (SWS) public water supply source at Sompting (located approximately 3.5km to the north east of the site) is situated in an area where salinity has been recorded the furthest inland.

However, the SWS Northbrook public supply borehole (located 1.8km to the north of the site) is reported to only have chloride levels of 32mg/l. **Table F2-2** summaries the historical information available on the saline monitoring boreholes within the Worthing Chalk Block.

Table F2-2: Worthing Block – Saline monitoring boreholes (BGS, 1999)

Borehole	Approximate Distance from the site (km) and direction	Distance from coast (km)	Electrical Conductivity (EC) (μS/cm)	Comments
Glynde Ave	4, SW	0.4	Increases with depth, up to 4000 μS/cm at 104m bgl	Fresh to brackish at 60m. Low EC for borehole in close proximity to sea
Victoria Park	0.4, W	0.6	Up to 4650 μS/cm at depths >150mbgl	Possible brackish pore water between 58m and 85m
Broadwater Elms	1.2, NE	1.75	<600	Maximum EC of 1200 μS/cm recorded in October 1986
Lancing	1.6, NE	1.25	General increase from ~600 (1983) to 650–700 (1999)	Occasional peak to ~900 μS/ cm
Sompting OB	2, NE	3	400	EC up to 2000 μS/cm at low groundwater levels; peaks at 72m and 100 m depth

Note: Data may not reflect current groundwater quality due to date of published report

Hydrology

The nearest surface water body to the site is Sussex Bay located approximately 600m to the south of the site. The culverted Teville Stream flows through Worthing town in a south easterly direction from its source near Tarring to its discharge point into the English Channel at Brooklands Lake, approximately 2.6km to the east of the site.

Groundwater Flooding

Groundwater flooding is caused by the emergence of water at the ground surface from sub-surface permeable strata particularly in low lying areas / valleys during periods of high groundwater levels associated with increased recharge typically due to significant rainfall events.

The Adur District Council and Worthing Borough Council Strategic Flood Risk Assessment (SFRA) (Map 15 Indicative Groundwater Flood Risk - Areas Susceptible to Groundwater Flooding) indicates that the risk of groundwater flooding at the site is low, with a less than 25% risk of groundwater emergence (See Figure **F2-3**).

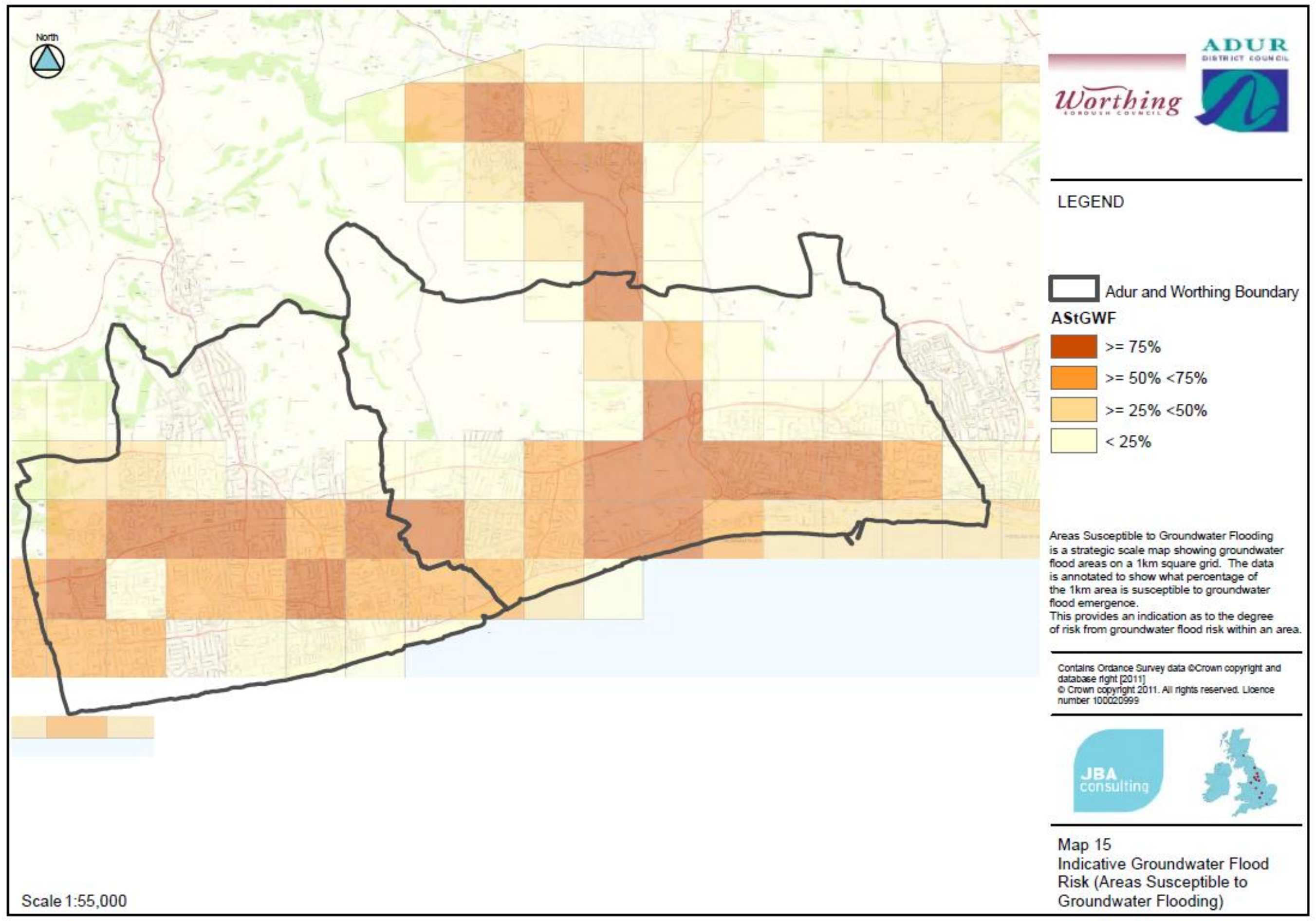


Figure F2-3: GW Flood Risk Map

SFRA indicated a few occurrences of groundwater flooding have been noted during the period of 1960 to 1990 across the study area. Groundwater flooding across West Sussex was recorded during 1974, notably in the River Adur catchment. Significant groundwater flooding was also observed during 1993/94, 2000/01 and 2002/03. **Figure F2-4 (overleaf)** shows the Environment Agency Flood Risk Designation for the area.

Although the risk of groundwater flooding is considered low, it is understood that the SFRA assessment suggests that properties in the area with basements can be at risk of flooding, as a result, the CEC Flood Risk Assessment report recommended as a precautionary mitigation measure, that any basements within the proposed development on the site should include raised floors to further mitigate any risk of groundwater ingress during seasonally high groundwater levels.

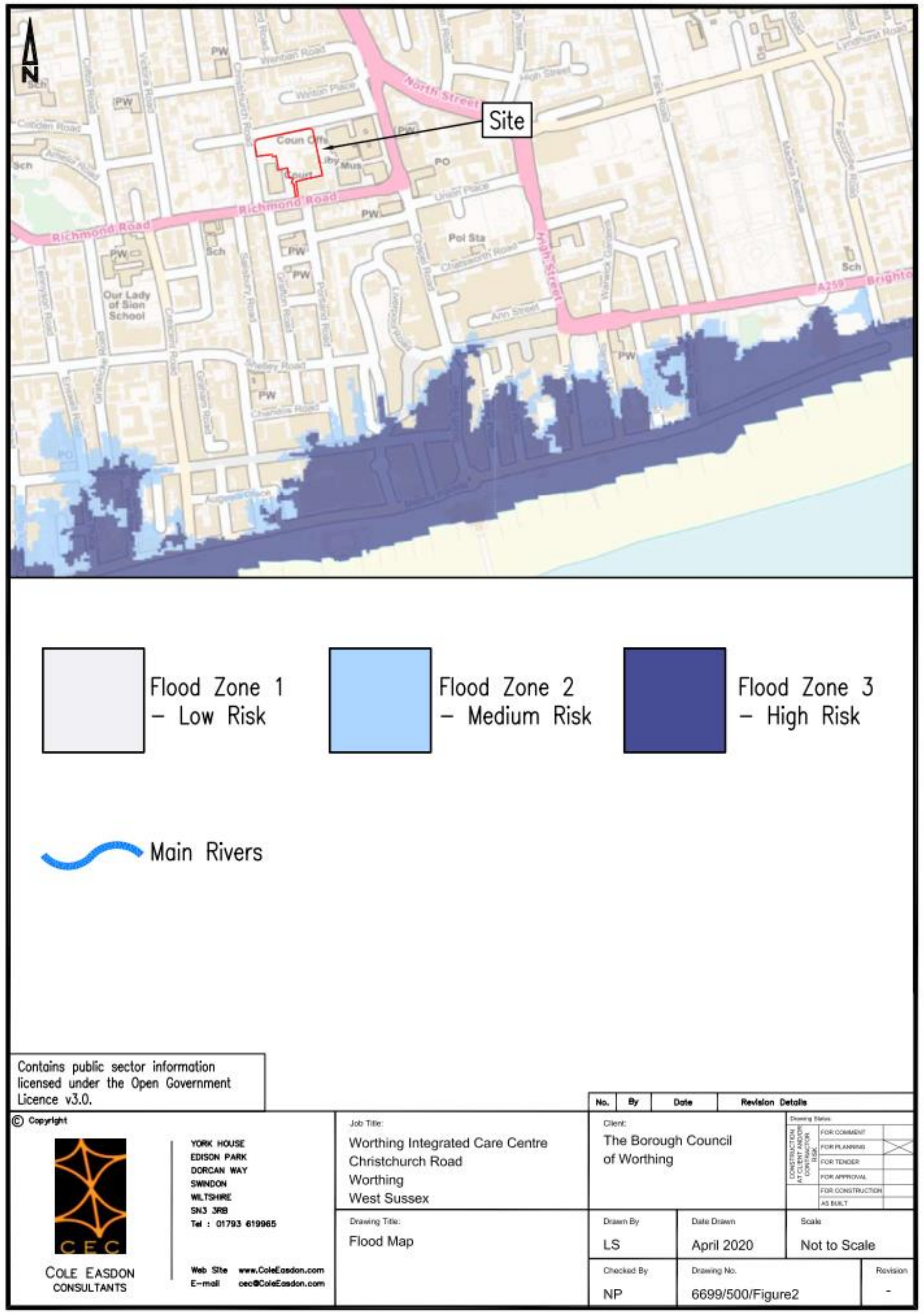
Summary

Based on the review of the available hydrogeological information for the area, it is considered that the site is underlain by unconfined Chalk with shallow groundwater at depths of between 4m and 10m bgl with a potential that during periods of high groundwater conditions, the groundwater level could rise higher by up to 1m. There is a also small potential that the groundwater beneath the site could be brackish.

Yields from boreholes in the Chalk aquifer vary significantly with transmissivities varying from 16 m^2/d to 9500 m^2/d with a median of 440 m^2/d. Yields between less than 1l/sec and 9.5l/sec and drawdowns between 0.2m and 9m are reported.

Although the risk of groundwater flooding is low, the flood risk assessment recommended raised floors levels for any basement buildings to minimise the potential risks of groundwater ingress during seasonally high levels.

Figure F2-4: Flood Risk Map (CEC, 2020)



Aquifer potential

Based on a review of the hydrogeological conditions at the site and surrounding area, it is considered that abstraction rates in excess of 5.0l/sec (432m^3/day) could be achieved from suitably drilled boreholes into the Chalk aquifer on the site. Historical abstraction records from nine public water supply boreholes within 2km – 4km of the site at Northbrook and Broadwater in the Worthing Chalk Block indicate abstraction rates of between 7Ml/d and 22.5Ml/d. This further suggests that sufficient yields are possible in the vicinity of the site.

However, there is a small risk of abstracting brackish or saline water given the proximity to the coast and information reviewed. This will have a potential long-term impact on the infrastructure.

The borehole yield and the radius of influence for any abstraction would be dependent on the level of fracturing within the Chalk aquifer and degree of connection across the area. The sustainable yield of any borehole and the potential impact on the local groundwater conditions can only be confirmed through testing of a pilot borehole on the site.

The area of the Chalk aquifer which includes the site currently is designated as 'Water Available' by the Environment Agency and therefore there should be no objection in principle to a new abstraction from the Chalk aquifer at the site provided there is no detrimental environmental impacts or derogation of other abstractions in the area. There is no information available on existing private groundwater abstractions in the vicinity of the site. This needs to be verified if the scheme progresses to the next phase.

Aquifer recharge constraints

It is generally easier to abstract water than to recharge water back into aquifers. This depends on the aquifer properties such as the transmissivity of the aquifer in the recharge area and the presence of a sufficient unsaturated zone thickness to accommodate the recharge head. Available groundwater and ground level conditions across the area suggest that the groundwater below the site is likely to be shallow, between 4m and 10m bgl and potentially up to 5m above the surface of the Chalk. As a result, the Chalk aquifer is fully saturated.

Although the available pumping test data from the Chalk aquifer in the area indicate limited drawdowns suggesting that recharge may not be a significant constraint, the naturally shallow groundwater level at the site already above the surface of the Chalk and the risk of higher seasonal levels is of significant concern for any aquifer recharge for a GSHC scheme. Even with only modest drawdowns, there is a risk that recharge could result in groundwater flooding in the vicinity of the recharge boreholes. Higher groundwater levels on the site due to recharge is also likely to impact on existing or proposed basements on and in the vicinity of the site.

Given the limited unsaturated zone thickness and the uncertain seasonally high levels, it is considered that there is insufficient depth of unsaturated zone to allow for sustainable re-injection of abstracted groundwater for a GSHC scheme without other adverse environmental impacts such as increased flood risk on the site and in the surrounding area.

In aquifers where there is potential for significant groundwater flow through fractures such as the Chalk, there is also a risk of increased temperature of the abstracted water from recirculation of the recharged water back into the aquifer (during cooling mode) and of lower temperatures when in heating mode. These also have the potential to impact on the long-term sustainability of the scheme. To reduce the potential for recirculation of the recharged water, the distance between the abstraction and recharge boreholes should be maximised within the confines of the site. The distance should be no less than 100m.

Conclusions and Recommendations

Conclusions

Based on the assessment of the available geological and hydrogeological information for the proposed development site at Worthing and the surrounding area, the following conclusions can be drawn: -

- The development site is underlain by a layer of made ground directly overlying River Terrance Deposits comprises clays, sand and gravels to depths of approximately 6m to 10m;
- The Chalk surface including a possible weathered surface layer is present between 6m and 10m below ground level.
- Topographically, the ground surface across the site is relatively flat at approximately 9m to 10m AOD and the site is approximately 600m to the north of the coast.
- The Chalk is a principal aquifer of regional importance as a source for public and private water supply in the area. Groundwater flow in the Chalk principally is via fractures, with very limited intergranular flow.
- The overlying River Terrace Deposits are likely to be in hydraulic continuity with the Chalk aquifer.
- It is estimated that the groundwater level within the Chalk on and in the vicinity of the sites is between approximately 4m bgl (5 to 6m AOD) and 10.2m bgl (1.2 to -0.2m OD). However, no detailed groundwater level monitoring data is available at the site.
- It is possible that groundwater levels could rise by up to 1m during seasonally high periods.
- Groundwater flow in the Chalk aquifer beneath the site is in a southerly direction towards the coast and Sussex Bay;
- No site-specific groundwater quality is available. However, historical records in the area suggests potentially brackish water may be present in the area due to the proximity to the coast and other smaller brackish watercourses in the catchment.
- The site is considered to be at low risk from groundwater flooding. However, recommendations in the flood risk assessment includes the use of raised floor levels in basements as a precautionary measure.
- Historical records from boreholes in the area indicates that boreholes in the Chalk aquifer are capable of providing sustainable yields in excess of 5l/sec (432m^3/day) with little drawdown. However, it is likely that borehole yields and drawdown will vary across the area depending on the nature of the Chalk strata and in particular the extent of fracturing;
- It is considered that the shallow rest water level (less than 10m) combined with the proximity to the coast, the potential for higher groundwater levels during seasonally high periods and the potential for impacts on any proposed or existing basements structures are significant constraints on the recharge capacity of the proposed GSHC;
- Accordingly, it is considered that the potential environmental risks and the limited unsaturated zone in the Chalk aquifer underlying the site are potential significant constraints for a sustainable operation of an OL-GSHP scheme on the site. However, the following recommendations are made for further consideration.

Recommendations

There are potentially 3 options for progressing an open-loop GSHP solution for the site:

1. Due to the potential constraints identified, it is likely that a standard open loop system with discharge back into the aquifer may not be feasible on the site, however, if it is decided to consider this option further, it will be necessary to carry out further investigation which will include the following:
   – Appoint a water well drilling contractor to drill at least two suitably designed pilot boreholes on the site (one abstraction and one recharge at selected locations, at least 100m apart) and test pump the boreholes to confirm the sustainable yield, groundwater quality and the recharge capability of the aquifer.
   – A consent to investigate and test pump will be required from the Environment Agency under the Water Resources Act 1991 to enable this investigation.
   – The test pump will include an abstraction and recharge test following installation of the boreholes; and
   – A hydrogeological impact assessment will need to be undertaken to confirm that there are no potential impacts of the proposal on existing water users in the area as well as the risks of groundwater flooding due to recharge activities.
2. An alternative option which is likely to be more cost effective and feasible could be considered. This involves abstraction from the Chalk aquifer for use in the heating / cooling and then recharge to the sewer network in the vicinity of the site. Only one borehole will be required for this option, hence a cost saving, however it will be a consumptive abstraction and will depend on the following:
   – Discussion with the Environment Agency to confirm their current position on any proposed consumptive abstraction from the aquifer. Given the current aquifer status of 'Water Available' based on the Environment Agency designation and any abstraction from the site is only likely to be intercepting the natural baseflow discharge to the coast, in principle, it is considered that the Environment Agency are unlikely to object to this option. However, it will depend on the proposed abstraction rates and the findings of a hydrogeological impact assessment;
   – The discussion will be followed by appointing a contractor to drill and install a suitably designed pilot borehole and test pump to confirm the sustainable yield from the aquifer and the variation in the groundwater quality. A consent to investigate and test pump will also be required from the Environment Agency under the Water Resources Act 1991 to enable this.
   – Completion of a hydrogeological assessment to assess the potential impacts of any abstraction on other groundwater uses in the aquifer;
   – Investigation of the network and sewer capacity in the vicinity of the site and confirmation of the capital and operational cost for any proposed discharge to the sewer as part of the scheme. A discussion and agreement will be required with Southern Water for this purpose. Information supplied by southern water shows that a 300mm combined sewer runs along Richmond Road to the south of the site. The capacity will need to be verified with Southern Water.
3. A third option will be to install a single abstraction borehole as in option 2 above and assess the feasibility of discharging the water directly to the coast. This option will involve a significant infrastructure requirement to lay the discharge pipe from the site to the coast, approximately 600m away. It is considered that this is likely to be prohibitively expensive for such a scheme.

For both options 1 and 2, to complete the investigation works, a number tasks will need to be considered, this includes a site visit to determine suitable borehole(s) location, design of the borehole(s), preparation of tender documents for the drilling and test pumping of the borehole(s). Obtaining the consents from the Environment Agency to carry out the investigation, contractor procurement, discussions with stakeholders, completion of the field works and hydrogeological assessment.

If the test pumping of the borehole(s) proves the feasibility of the project, applications can be made to the EA under the Water Resources Act 1991 for an abstraction licence for the pumping borehole and for an environmental permit (if necessary) for the recharge operations or permit discharge to the sewer as appropriate.

A typical timescale for completion of this up to licensing is between 9 to 12 months.

F.3 Sewer Source Heat Pumps

To ascertain the viability of a SSHP system to meet the heating requirements of the Civic Quarter site, a high-level technical analysis has been undertaken in conjunction with Landmark Wastewater services. This analysis is summarised below.

Summary

The wastewater within the sewer systems contains latent thermal energy, particularly sewage due to heated water discharge from showers, washing machines and other appliances. This heat is captured by abstracting and passing a percentage of the wastewater flow in any given sewer through a plate-heat exchanger assembly, which is specially designed to account for the nature of the fluid, prior to reinjection back into the sewer.

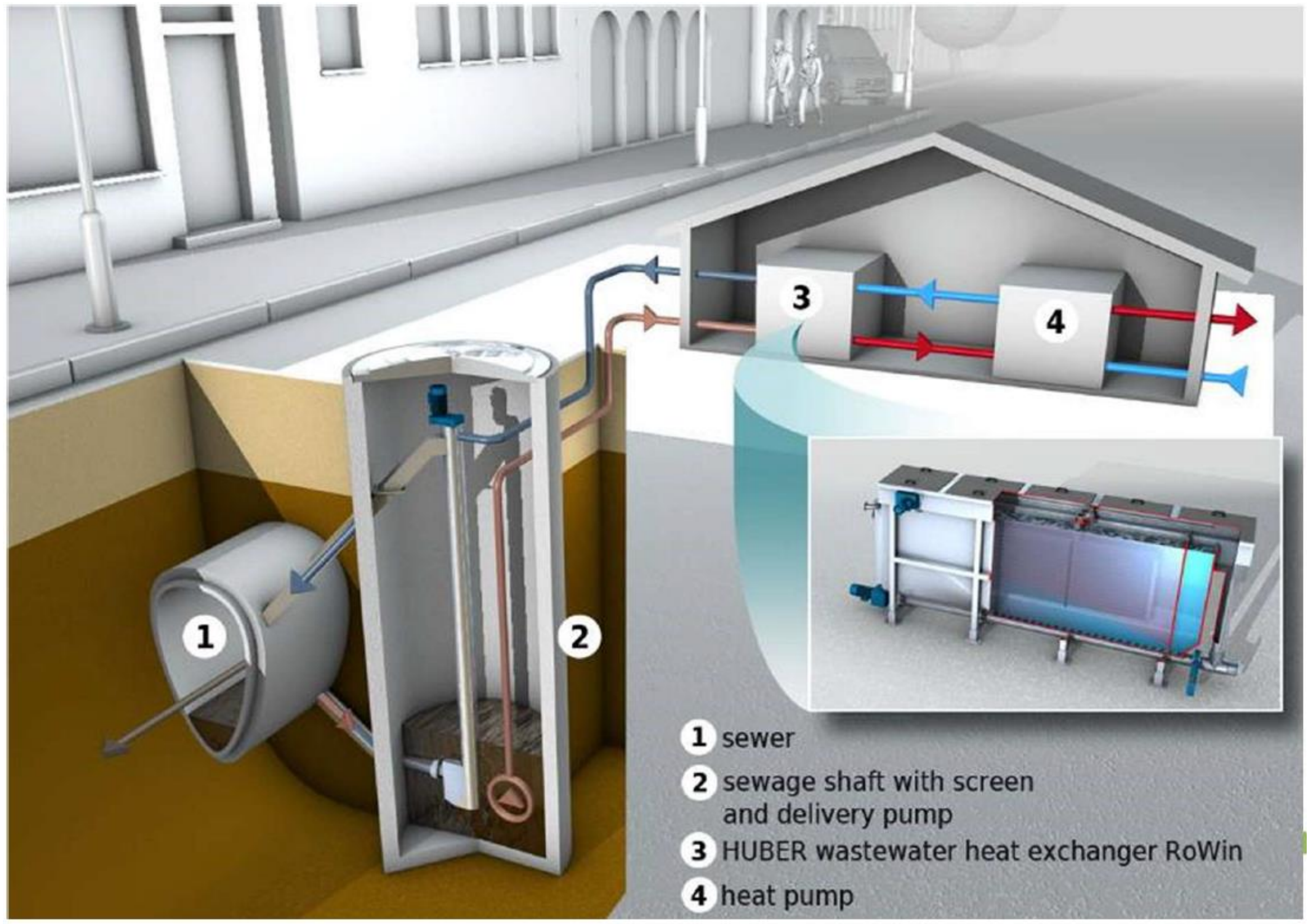


Figure F3-1: Overview of Landmark / Huber's technical solution. Note that alternative systems are commercially available.

Sewer Locations

It is estimated that a sewer with a diameter of over 900mm or larger is required for a system to be economically feasible.

A map of the local sewer network in and around the Civic Quarter site was obtained from Southern Water, the network operator. It was identified that a large diameter sewer (Ø1,500mm) is located approximately 210m east of the boundary of the Civic Quarter site, running from North to South down the A259. The sewer also runs adjacent to the Union Place development site.

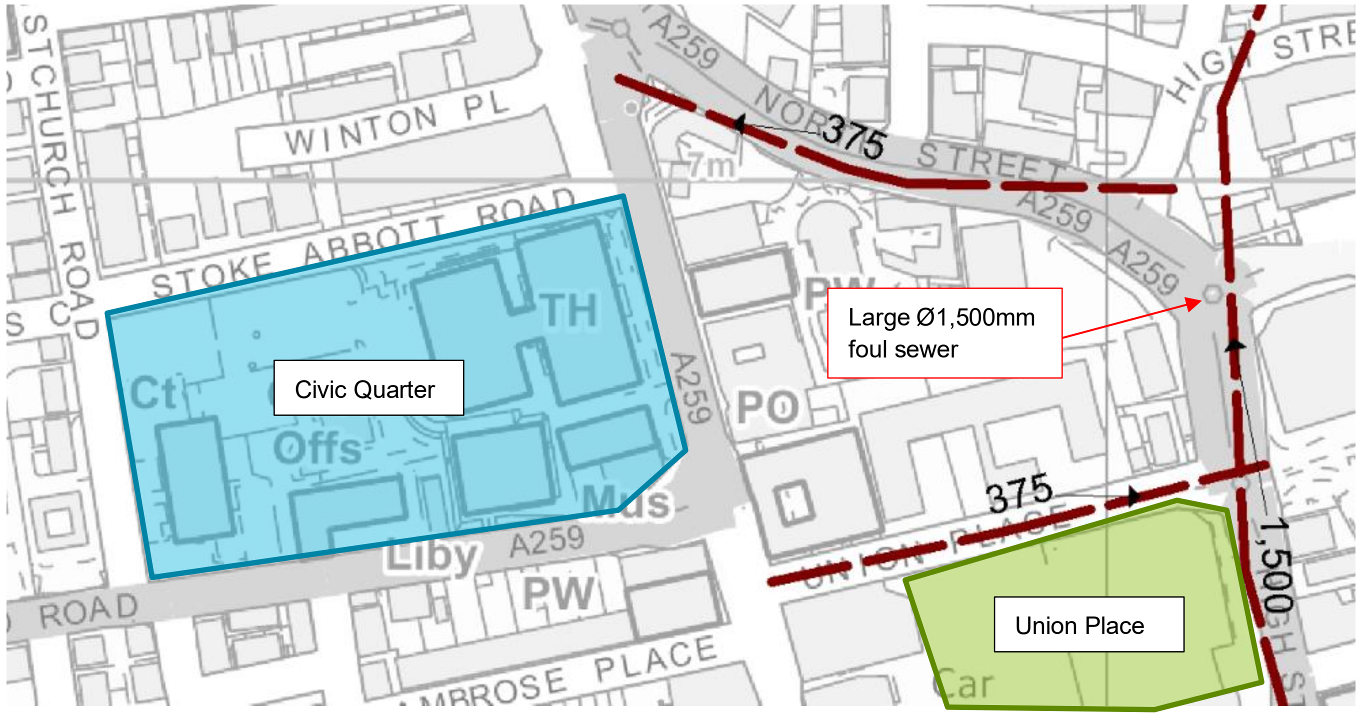


Figure F3-2: Location of large diameter sewer in respect to Civic Quarter and Union Place site. Map courtesy of Southern Water

Sewer Flow Rates

Following the identification of a suitable sewer line, further information pertaining to the wastewater flow rates within the sewer was obtained from Southern Water, as detailed in Table F3-1 below.

Table F3-1: Sewer information obtained from Southern Water

Parameter	Value
Catchment Area	East Worthing
Average Depth	9.9 – 10.5m
Shape	Circular
Material	Concrete
Type	Foul only (no surface water)
Wastewater Flow Rate	1,250 – 2,070 litres per second

Based on the flow type (foul water only) and flow rate information, it is anticipated that the maximum thermal capacity of a sewer source heat pump system installed on the sewer line is circa **3.3MW.**

F.4 Air Source Heat Pumps

Air Source Heat Pumps (ASHPs) extract energy from the ambient air and are able to function even when temperatures are as low as -5°C.

To extract energy from the ambient air, a portion of the equipment, the collector coil (which functions as either the condenser or compressor depending on if the heat pump is in heating or cooling mode respectively) is located externally. This is typically achieved by placing the coils on roof-spaces (which are flat to enable plant access) or at ground level, as illustrated in Figure F4-1 below:

Figure F4-1: Large capacity ASHP installation examples: Rooftop installation (left) or ground level installation (right, unit shown is 700kW in size and 8m in length, image courtesy of Star Refrigeration).

To absorb enough energy from the air, the resultant the collector coil(s) will need to be very large to serve the demands of a centralised district heating system, which typically results in the plant solution taking up a larger footprint than the other viable heat pump solutions discussed in this section. Based on the available space identified within the Civic Quarter, the maximum installable plant capacities are estimated in Table F4-1 below:

Table F4-1: ASHP capacity limits at identified EC locations.

Energy Centre Location	Available footprint	Estimated ASHP plant capacity limit, based upon AECOM developed spatial benchmarks
WICC Roof-space	155m^2, shared with AHU plant	Up to 2MW
MSCP	201m^2	4MW (if adequate ventilation is ensured or walls are removed)
Town Hall Basement	364m^2	0MW – restricted access to external areas result in ASHP being unsuitable for installation at this location, unless space allowance can be allowed for on the flat portion of the courtyard roof-space.
Union Place Development	TBC	Large potential for plant is available, should it be incorporated into the design (i.e. via inclusion of flat roof spaces or allowance for a ground level installation)

Based on the above analysis, it is anticipated that sufficient ASHP plant to serve the Civic Quarter site can be located on either the WICC roof-space, MSCP plant room location or at Union Place development site.

F.5 Gas Combined Heat and Power Reciprocating Engine

CHP or cogeneration refers to the simultaneous generation of heat and electricity from the same process. Conventional electrical power generation is centralised in the UK and normally located away from other buildings or businesses. Electrical power generated at these stations generates a significant amount of heat that is wasted, and significant losses also result from the transmission to consumers. By contrast, a CHP system tends to be located close to the end user. As such, the heat by-product of electrical generation can be captured and sold as a commodity to local customers.

CHP plants can reach overall energy efficiencies in excess of 80%, compared with 35% for traditional power stations. CHP systems use one of a number of prime movers, including a turbine-based system, and reciprocating (piston) engine types. Each of these technologies has individual characteristics that best lend their use to certain applications and situations. Reciprocating engines (the technology type most commonly deployed in networks of the scale expected to be appropriate for Worthing) are essentially internal combustion engines that operate in a similar way to car engines. Instead of providing mechanical drive however, the pistons drive a shaft to generate electricity. Different grades of heat are recoverable, including from the exhaust gases (high-grade/temperature heat, ~450°C), from the jacket of the unit (low-grade/temperature, ~90°C) and intercoolers (low-grade/temperature, ~40°C). Typically, intercooler heat is expelled to atmosphere.

CHP technology is best deployed in buildings/areas that have a high and consistent demand for heat, such as for space heating, water heating and process heating (e.g. sterilisation, chemical heating in industrial operations). Consideration should also be given to how electricity generated by the CHP will be utilised. Options include using the electricity onsite to offset grid consumption; to export directly to the grid; to agree a Power Purchase Agreement (PPA) with a 3rd party user to ‘sleeve’ electricity generation through the grid to the user; and the use of a private wire to distribute electrical generation directly to a 3rd party.

This level of operation allows for further financial saving through the bulk buying of fuel at lower prices. How the generated electricity is utilised (and therefore the price at which it realises a value) also plays a key role in the economic performance of the system.

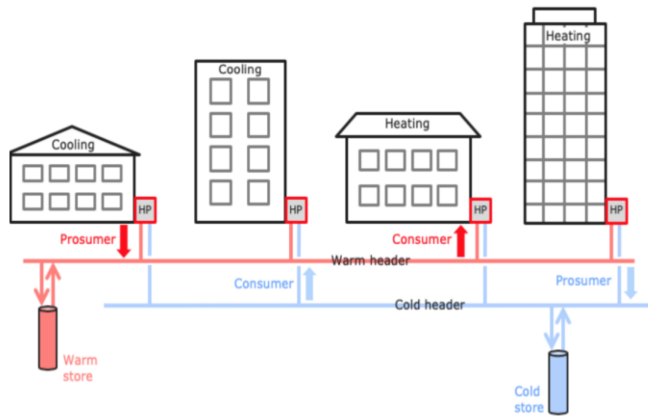
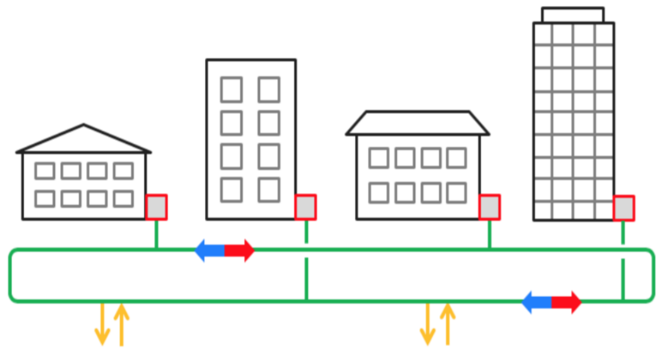
Because the benefits of gas-CHP are derived from the production of electricity that is cleaner than that which is taken from the grid, the CO2 saving benefits of gas-CHP are likely to reduce over time if, as outlined by the Department of Energy and Climate Change (DECC – now BEIS) emission projections, the CO2 emissions attributed to grid electricity fall. Grid decarbonisation is projected to occur over the next 40 years due to further integration of green generation technologies and the increase in efficiencies of fossil fuel generation processes. However, it is expected that gas-fired CHP will continue to be an effective technology in reducing carbon emissions until the 2030s.

Gas-fired CHP systems typically have higher NOx emissions than individual gas boilers and post combustion treatments (e.g. catalytic and non-catalytic abatement technologies) may be needed to ensure air quality is not significantly affected.

Gas-CHP is a proven technology and has numerous examples of working and reliable application throughout the world and within the UK. The technology offers levels of flexibility as it allows modular build-out. Plant can be installed in conjunction with network phasing, resulting in the optimisation of supply and demand.

Appendix G – Potential Delivery Network Solutions

Given that there is both a heating and cooling load present across the project scope area, there are a number of different technical network solutions that could be implemented. The features of each solution are discussed in the table below.

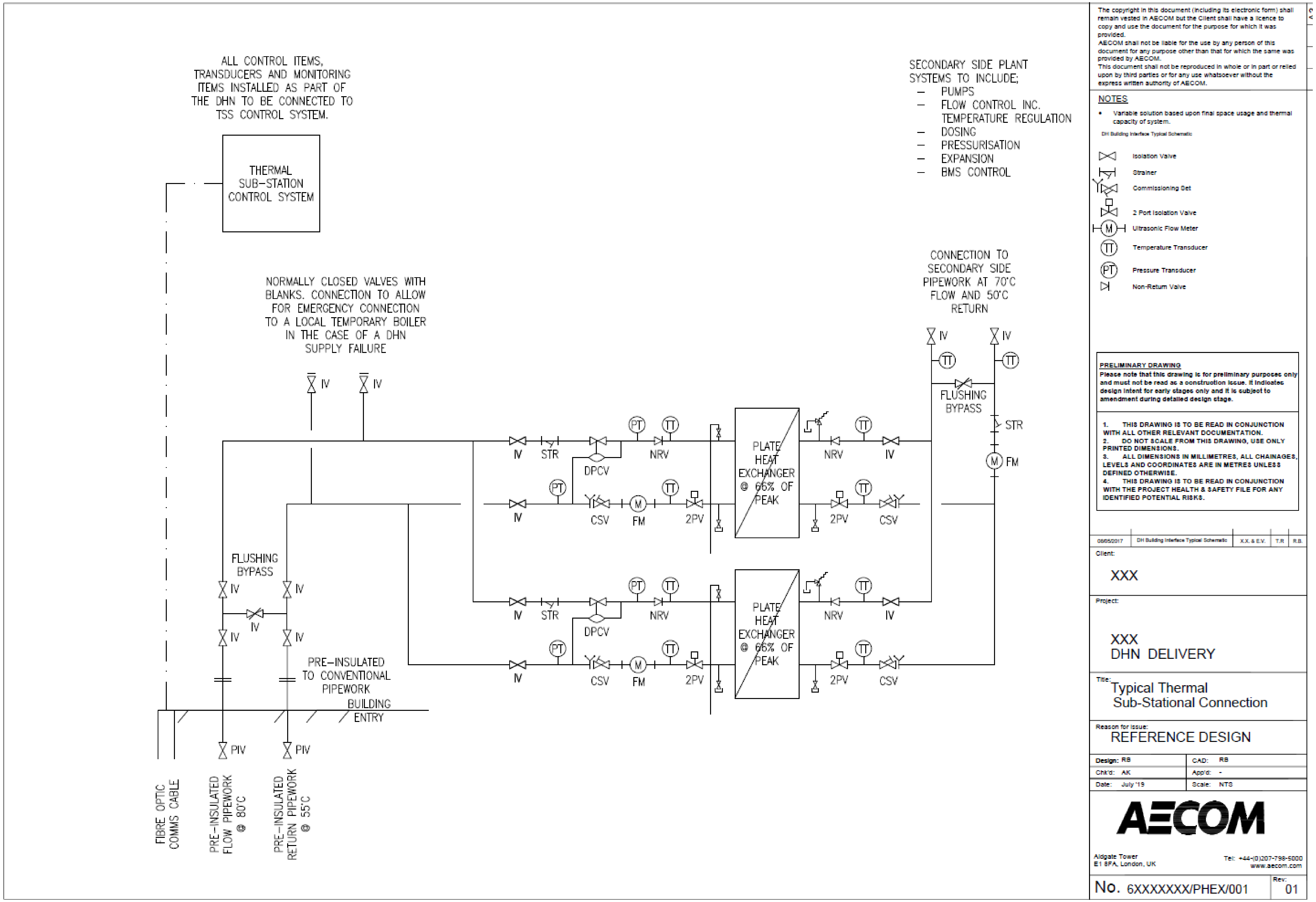
Solution ID	Description	Illustration	System Requirements	'Typical' Operational Temperatures
Third Generation	All heating and cooling is generated from a centralised energy centre and distributed in two different pipework networks, which operate in isolation from one another. Can utilise any form of generational technology.		Can serve either one of or both heating and coolth to any site, including buildings operating with 'historical' heating temperatures of 82/71°C flow and return.	85-75°C heating network 6-12°C cooling network.
Fourth Generation	Third generation heating networks operate at a higher temperature, aligned with historical building heating temperatures. Fourth generation heating networks operate at reduced temperatures to enable improved heat pump performance whilst still enabling the storage of domestic hot water at 60˚C.		Buildings' heating systems need to operate at lower than 'historical' ones. May require some secondary side conversion works to be undertaken in existing facilities.	60-30°C heating network 6-12°C cooling network.
Fourth Generation with Prosuming	A variant on the fourth-generation system described above, albeit with the generational plant having to be heat pump based. When a heat pump operates in heating mode, waste coolth energy is generated, and vice versa. In a 'prosuming' system, this waste energy is recovered within the EC and distributed via the appropriate network, increasing the effective efficiency of the heat pump plant.		Requires both a heating and cooling network in operation, and plant for each system located within the same Energy Centre(s). Suitable when the heating and cooling loads are unbalanced, i.e. the annual cooling requirements are less than 50% of the heating requirements. . Buildings' heating systems need to operate at lower than 'historical' ones. May require some secondary side conversion works to be undertaken in existing facilities.	60-30°C heating network 8-16°C cooling network.
Fifth Generation (Dual Pipe)	As with third and fourth generation systems, this system includes separate heating and cooling distribution networks, although they are operating at much lower temperatures. These networks provide a source for decentralised heat pump plants, which are located within each connected load on the network. This plant can generate heat and coolth at the temperatures required within the building. The rejected heat and coolth from the operation of the heat pumps is captured within the appropriate network for use within other sites. Long term 'inter-seasonal' storage can be included to share energy across the typical heating and cooling seasons. The system can also (where required) contain centralised 'top-up' plant within centralised energy centre(s). These are able to maintain network temperatures once inter seasonal storage maximum capacities are reached.		Requires both a heating and cooling network in operation. Suitable when the heating and cooling loads are well balanced, i.e. the annual cooling requirements are more than 50% of the heating requirements.	30-10°C heating network 20-10°C cooling network.
Fifth Generation (Single Pipe)	Same generational plant arrangement as above dual pipe fifth generation system, with building-based heat pumps and balancing plant in energy centre(s) if required. However, this system is based on a single pipe solution, which provides the temperature sink for the building-based heat pump when operating in either heating or cooling mode. All rejected energy from heat pump operation can be captured in within the network loop as required.		Buildings' heating systems need to operate at lower than 'historical' ones. May require some secondary side conversion works to be undertaken in existing facilities.	15-20°C shared heating and cooling network

Appendix H – Delivery Network Design Elements

H.1 Buried Utilities / Constraints Map

H.2 Sketch of Pipework Routing Within Library Loading Bay / Podium Car Park

H.3 Typical Thermal Substation Design



Appendix I – Modelling Assumptions

I.1 Heat Pump Capacities & Performance Parameters

Following the feasibility assessments included in Appendix F, the maximum thermal outputs from the LZC systems has been assumed as below

System	Location	Limiting factor	Max. thermal output	Efficiency at 65°C flow	Efficiency at 85°C flow
OL-GSHP	WICC development site	Single borehole yield	350kW	370%	290%
CL-GSHP	WICC development site	Prevention of long-term cooling of ground	200kW	363%	286%
SSHP	Union place development site	Southern water modelled effluent flow rate	3,300kW	381%	297%
ASHP	Any	None	None	287%	232%

Table I-1 – LZC thermal output maximum capacities

I.2 Alternative Decarbonisation Costs – BaU 3; Building Level ASHP Installation

Building	Plant Capacity	Estimated Capital Cost of Plant Installation
Town Hall	120kW	£84,000
Assembly Hall	120kW	£84,000
Portland House	450kW	£315,000
Museum	120kW	£84,000
Library	200kW	£210,000
Law Courts	600kW	£420,000
WICC	116kW	£81,200
Total		**£1,278,200**

Table I-2 – Capital cost of works under BaU 3; Building Level ASHP Installations

I.3 Modelling Timing Assumptions

The model assumes that network operation will start in 2022, in accordance with the anticipated completion of the WICC development site.

I.4 Modelling CAPEX Assumptions

Values are derived from AECOM experience and suitable industry standards (such as SPONS), which have been back checked with contractors during the tender stages of other DH projects to ensure that values are up to date and accurate. In line with a RIBA Stage 2 design, costs are accurate to ±30%.

The key assumptions made in the estimation of the capital costs (CAPEX) of each network option are given below. The model updates the CAPEX values to reflect the user-selected parameters, for example whether a given building is included in the calculations.

I.5 Modelling Asset Replacement Cycle Assumptions

The following assumptions have been made on the required replacement cycles of plant and equipment on the basis that a like-for-like replacement will be sought throughout the network lifespan. All other plant and equipment is assumed to last beyond the project lifetime, or is funded by ongoing maintenance costs. Plant replacement at the end of the lifespan is assumed to be accounted for an additional CAPEX cost items when required.

Technology/asset	Replacement cycle	Source
EC boilers, incl. ancillary equipment	Every 20 years	CIBSE Guide M
Gas CHP	Every 100,000 hours operation	Manufacturers data
Heat pumps	Every 20 years	Manufacturers data
Heat exchangers	Every 15 years	Manufacturers data
Heat distribution pipework and civils works	Every 50 years	Manufacturers data

Table I-2 - REPEX assumptions

I.6 Modelling OPEX Assumptions

Fuel Costs

Projected fuel unit prices for gas and electricity are based on energy price analysis published by the Department for Business, Energy and Industrial Strategy (BEIS) for industrial customers.

Within the Green Book tables, three bands of prices are given: High, Central and Low for three scales of power consumption: Large scale (Industrial), medium scale (Public Sector/Commercial) and small scale (Domestic). The 'central' price scenario has been used within the model to determine rates of real price inflation from the unit prices paid currently by all of the customers on the network.

The figure below shows the HM Treasury Green Book future fuel price projections, showing the Central scenarios for electricity and gas. Whilst the trend of these projections have been used in the model, the projections made in the Green Book do not show any change to price beyond c. 2030, an unlikely scenario. This could pose a risk for the viability of the network and thus it has been registered as a risk item in Appendix A.

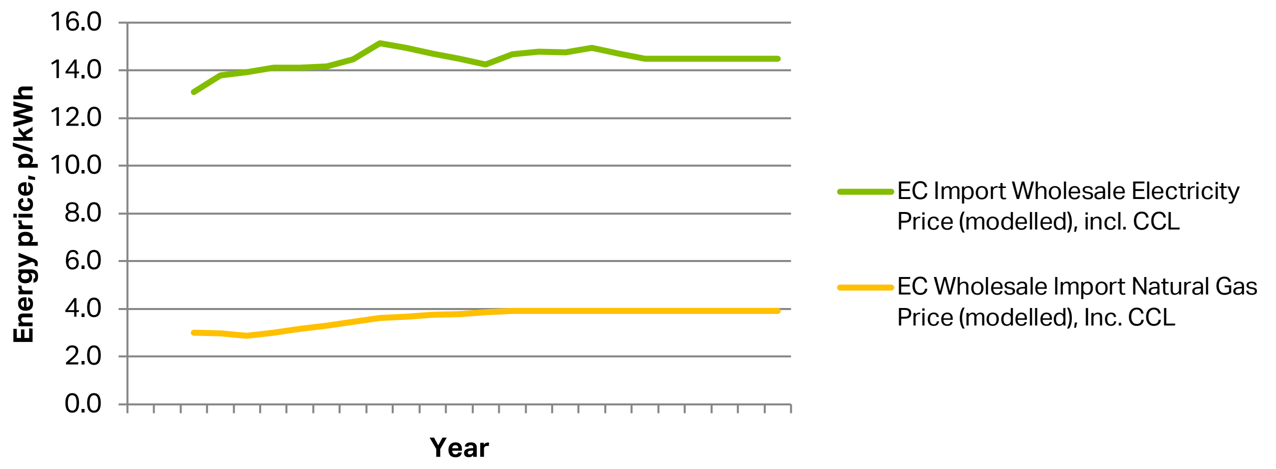


Figure I-1 – Commodity price projections

I.7 Maintenance Costs

Maintenance and staffing costs are assumed to be constant over the lifespan of the project. The figures given in the table below are based on AECOM experience and recent quotes from contractors and developers.

OPEX item	Metric	Based on
EC fabric	1% annually of total Energy centre CAPEX.	Undertaking PPM activities associated with the building. Primary activity will be clearing of gutters and rainwater drainage
All generation services.	2.5% p.a of total energy generation services CAPEX.	Value based on SFG20 assessment and based on PPM lead maintenance strategy with limited reactive time. Energy centre to be unstaffed for the majority of the time, other than PPM activities. Value includes allowance for consumables but not reactive replacement of components as this is covered under Sinking Fund
Pipework	2.5% p.a of total DHN distribution network CAPEX	Conventional PPM (as per SFG 20)
Private Cables	1% p.a of total private wire distribution network CAPEX	Conventional PPM (as per SFG 20)
Internal distribution systems	£1% p.a of total internal distribution networks CAPEX	Conventional PPM (as per SFG 20)

Table I-3 - OPEX assumptions

I.8 Sewer System Heat Extraction Costs

Following experience from previous projects, it is anticipated that Southern Water (the sewer system network operators) may seek to share the revenue generated by the project resulting from the use of their asset. The resultant fee, which is likely to be applied per unit of heat extracted, is negotiable and aimed at avoiding spoiling any potential scheme. A 0.5p/kWh charge has been included for this purpose in all modelling described in this report.

I.9 Modelling Parasitic Load Requirements

The model assumes that an 'parasitic' electrical load – accounting for the power used for pumping, water treatment, control systems and other small power use within the ECs – is applied every year in accordance with the level of thermal generation.

The level of power assumed to be required is equal to 5% of the total annual generation.

I.10 Modelling Revenue Assumptions

Revenue will come from a number of sources, including direct charges for heat and fixed charges for operation (comparable to standing charges on conventional utility services). For the CHP based options, revenue will also come from any electricity income (from CHP-generated electricity) which may be available through sales to the grid or directly to electricity consumers.

RHI has been excluded from all assessment based on the current forecast end date for the scheme (March 2022) occurring too early for the DEN scheme to realistically meet the required deadlines given the current development stage.

Furthermore, a one-off payment is anticipated to be paid by the both the WICC developer and Union Place are anticipated to help cover the cost of connecting each estate to the network. This fee is based upon the cost savings to be made by the developers as a result of the development of a DHN. In each case this corresponds to the cost of installing alternative means of thermal generation and domestic HIUs. In each case, a 10% discount against the BaU costs has been applied to encourage connection in light of no planning requirement being in place to necessitate it.

Development Site	Anticipated Connection Charge	Rationale
WICC	£73,000	BaU Costs to install ASHP plant
Union Place - Hotel	£11,000	BaU Costs to install ASHP plant
Union Place – Commercial	£6,800	BaU Costs to install ASHP plant
Union Place – Residential	£565,000	BaU Costs of £275,000 to install communal ASHP plant

Table I-4 – Connection fee assumptions

The counterfactual heat price used within the model has been developed for 3 different BaU scenarios. This is covered in detail within Section 2.3 of the main report.

The counterfactual cooling price used within the sensitivity assessment investigating the potential for the addition of a cooling network is based upon the fuel costs only of the existing centralised cooling plant in each applicable site. Costs relating to maintenance and replacement are omitted from this estimation on the basis that any district cooling system would not be a resilient solution and each site would require local backup.

The counterfactual power price used within the assessment of solutions that include CHP is based upon the blended electrical purchase tariffs paid by each building connected to the existing private wire network operated out of the Town Hall LV substation (serving the Town Hall, Assembly Hall and Law Courts).

I.11 Modelling Carbon Emission Assumptions

Scheme carbon savings depend on the input fuel and the associated carbon factors of the fuel which is being offset by the heat generation technology. Emissions associated with the combustion of gas are assumed to be constant over the lifetime of the project, where the emission factor used is 0.184kgCO_2e/kWh, based on UK Government GHG Conversion Factors 2018[21]. In cases where grid electricity is displaced by CHP electricity, carbon factors are taken from the BEIS bespoke CHP emissions factors[22] spreadsheet for electricity exported and used on site). This analysis accounts for the decarbonisation of the grid, where emissions are calculated based on the amount of electricity generated by the CHP that is used on site, as opposed to that which is exported. The model calculates the CO_2 emissions savings for each year of operation, based on the forecast carbon factors. Full project life savings will also be reported.

Presently, gas CHP currently delivers carbon savings as the electricity produced is cleaner than that which is taken from the grid. However, as outlined by the DECC emission projections, the CO_2 emissions attributed to grid electricity are expected to fall. As a result, the carbon savings associated with the use of gas CHP schemes is expected to decrease over time. In the case of installations consisting of smaller engines with relatively high Heat to Power ratios, it is anticipated that they will become net carbon generators (against the BaU case) in the early 2030's.

[21] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/526958/ghg-conversion-factors-2016update_MASTER__links_removed__v2.xls

[22] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/446512/Emissions_Factors_for_Electricity_Displaced_by_Gas_CHP.xlsx

I.12 Modelling Scheme Ownership Assumptions

The model assumes the network is operated by a separate entity, referred to as the 'ESCo', or Energy Supply Company. Costs are borne by the new company, and if the network includes WBC buildings, then they are treated as any other customer on the network, experiencing the same costs and savings as the other customers.

I.13 Modelling Discount Rates

Discount rates are used to represent the future value of money spent now. In the UK, the government makes decisions based on 'discounted Net Present Value (NPV)', which is a calculation that helps inform whether a capital outlay made today will be worthwhile in the future. The model assumes a constant discount rate over the life of the network of 3.5%[23].

I.14 Financing Options

The model does not consider at this stage the impact of financing (e.g. the cost of raising finance, servicing debt, debt limits, types of credit etc.). The next stage of this study will advance the modelling of a chosen network option, accounting for these elements.

I.15 Tax

VAT is not included in the model as it only has a small impact on the cashflow due to the short construction period. Since this overlaps with operation it is therefore not be expected to impact the feasibility of the project.

[23] Based on values taken from https://data.gov.uk/sib_knowledge_box/discount-rates-and-net-present-value,

Appendix J – Modelling Outputs

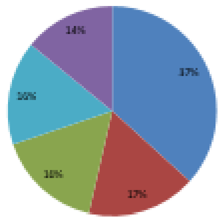
TEM output models issued as separate files alongside this report, with headline results shown below.

J.1 Developed Solution 1 Results – OL-GSHP System

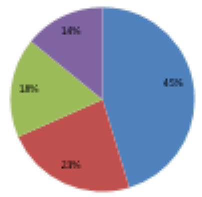
Worthing; Scenario: OLGSHP & Gas Boiler — Project Dashboard

Network Characteristics		
Number of Diff. Temp. Networks	1	
Flow Temperature	55-65	°C
Return Temperature	25-35	°C
ΔT	25-35	°C
Peak Heat Load	900	kW
Annual Heat Load	2,400	MWh/yr
(Thermal Losses)	350	MWh/yr
Heat Pump Heat Generation	2,100	MWh/yr
Biomass Heat Generation	0	MWh/yr
CHP Heat Generation	0	MWh/yr
Gas Boiler Heat Generation	300	MWh/yr
% Low Carbon Heat	88%	
Load Factor [1]	30%	

Proportion of Energy Load by Sector	
Office	37%
Theatre	17%
Community	16%
Courts	16%
Clinic	14%



Proportion of Energy Load by Quality	
Benchmarked	45%
Real Hourly or Better	23%
Real Annual	18%
Energy Model	14%



Annual Energy	Heating	
Network Length	355	m
Annual Demand	2,362	MWh/yr
Energy Density	5.77	MWh/m

Energy Centre Plant	Now	Future
EfW/Waste Heat plant	●	●
Water Source Heat Pump	●	●
Air Source Heat Pump	●	●
Ground Source Heat Pump	●	●
Sewage/Wastewater Heat Reco	●	●
Gas CHP	●	●
Gas Boiler	●	●

Generation Plant Details		
Heat Pump Plant Thermal Rating	345	kW
CHP Thermal Rating	0	kW
CHP Electricity Rating	0	kW
Biomass Boiler Thermal Rating	0	kW
Gas Boiler Plant Thermal Rating	1,100	kW
Estimated Energy Centre Footprint	270	m²
Thermal Store Total Volume	50	m³

Network Analysis

Capital Costs		
Total Capital Cost	£1.89	million

Operating Costs		
Levelised Cost of Heat	8.70	p/kWh

Project IRR [2]	Without HNIP	With HNIP [3]
25 year IRR	-2.00%	3.72%
30 year IRR	0.09%	4.97%
40 year IRR	1.89%	6.00%

NPV (£million) At a discount rate of 3.5%	Without HNIP	With HNIP [3]
25 year NPV	(£0.76)	£0.02
30 year NPV	(£0.61)	£0.17
40 year NPV	(£0.39)	£0.38

Predicted CO2 Savings versus Gas Boilers	
25 year saving	73.70%
30 year saving	74.38%
40 year saving	75.23%

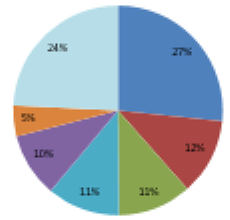
[1] Derived by dividing the total heat generated per year by the product of the peak output of the plant and the number of hours in a year (8760).
[2] Project IRR based upon heat tariffs equivalent to the operation of building level Gas Boilers at each customer site, including social cost
[3] HNIP intervention modelled of 42.47% of total CAPEX

J.2 Developed Solution 2 Results – SSHP System

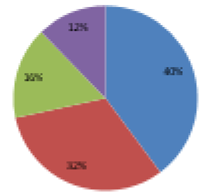
Worthing; Scenario: SSHP & Gas Boiler — Project Dashboard

Network Characteristics		
Number of Diff. Temp. Networks	1	
Flow Temperature	55-65	°C
Return Temperature	25-35	°C
ΔT	25-35	°C
Peak Heat Load	1,600	kW
Annual Heat Load	3,400	MWh/yr
(Thermal Losses)	499	MWh/yr
Heat Pump Heat Generation	3,400	MWh/yr
Biomass Heat Generation	0	MWh/yr
CHP Heat Generation	0	MWh/yr
Gas Boiler Heat Generation	0	MWh/yr
% Low Carbon Heat	100%	
Load Factor [1]	24%	

Proportion of Energy Load by Sector	
Office	27%
Theatre	12%
Community	11%
Courts	11%
Clinic	10%
Hotel	5%
Residences	24%



Proportion of Energy Load by Quality	
Energy Model	40%
Benchmarked	32%
Real Hourly or Better	16%
Real Annual	12%



Annual Energy	Heating	
Network Length	629	m
Annual Demand	3,370	MWh/yr
Energy Density	4.61	MWh/m

Energy Centre Plant	Now	Future
EfW/Waste Heat plant	●	●
Water Source Heat Pump	●	●
Air Source Heat Pump	●	●
Ground Sourced Heat Pump	●	●
Sewage/Wastewater Heat Reco	●	●
Gas CHP	●	●
Gas Boiler	●	●

Generation Plant Details		
Heat Pump Plant Thermal Rating	1,000	kW
CHP Thermal Rating	0	kW
CHP Electricity Rating	0	kW
Biomass Boiler Thermal Rating	0	kW
Gas Boiler Plant Thermal Rating	2,000	kW
Estimated Energy Centre Footprint	463	m²
Thermal Store Total Volume	50	m³

Network Analysis

Capital Costs		
Total Capital Cost	£4.29	million

Operating Costs		
Levelised Cost of Heat	11.30	p/kWh

Project IRR [2]	Without HNIP	With HNIP [3]
25 year IRR	-2.12%	3.81%
30 year IRR	-0.06%	5.00%
40 year IRR	1.74%	6.00%

NPV (£million) At a discount rate of 0.035	Without HNIP	With HNIP [3]
25 year NPV	(£1.59)	£0.06
30 year NPV	(£1.30)	£0.34
40 year NPV	(£0.88)	£0.77

Predicted CO2 Savings versus Gas Boilers	
25 year saving	88.87%
30 year saving	89.56%
40 year saving	90.43%

Predicted CO2 Savings versus local ASHPs	
25 year saving	23.92%
30 year saving	23.94%
40 year saving	23.96%

[1] Derived by dividing the total heat generated per year by the product of the peak output of the plant and the number of hours in a year (8760).
[2] Project IRR based upon heat tariffs equivalent to a 33% increase to the operation of building level Gas Boilers at each customer site, including social cost
[3] Maximum possible HNIP intervention modelled - 45% of total CAPEX (limted by state aid rules)

J.3 Preferred Solution - Customer Benefit Sheets

For simplicity, all of the customer benefit sheet presented in this section pertain to developed solution 1 (OL-GSHP).

Town Hall

Building / Estate ID:	Town Hall
Residential / Non-Residential:	Non-Residential
Existing or Future Development:	Existing
Modelled Connection Date:	2022
Annual Heat Demand:	621,648 kWh

Heat

System Details

Counterfactual Technology:	Gas Boilers	Technology:	District Heating Connection
Fuel Type:	Gas	Building as a % of Total	
Modelled Plant Size:	120 kW	District Heating Network Load:	28.43%
Plant Generational Efficiency:	86%		

CapEx

BaU / Current Costs		District Heating Connection Costs	
New Plant or Upgrade Installation Costs:		**Network Connection Fee:**	
Generational Plant:	£0	Discount Offered vs Counterfactual:	25%
Secondary Side Systems (In Building):	£0		
Gas Network Development:	£0		
Total Heating System CapEx:	**£0**	Total District Heating Connection Fee:	**£0**

OpEx

Running Costs:

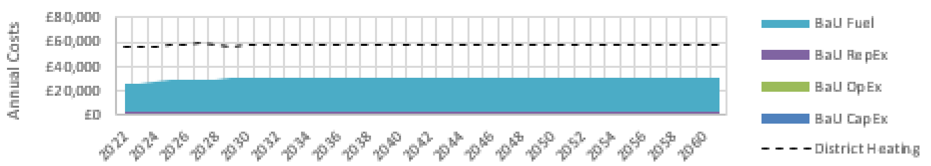
Running Costs:	2022	2062
Discount Offered vs Counterfactua	0%	
Blended Heat Tarff per kWh:	8.94	9.30
Total / year:	**£55,591**	**£57,787**

	Total	Av. pence/kWh		Total	pence/kWh
25 Year Costs:	£1,439,369	9.26	25 Year Costs:	£1,439,369	9.26
30 Year Costs:	£1,730,500	9.28	30 Year Costs:	£1,730,500	9.28
40 Year Costs:	£2,310,056	9.29	40 Year Costs:	£2,310,056	9.29

(increase in costs annually due to real price inflation of fuels)

TotEx

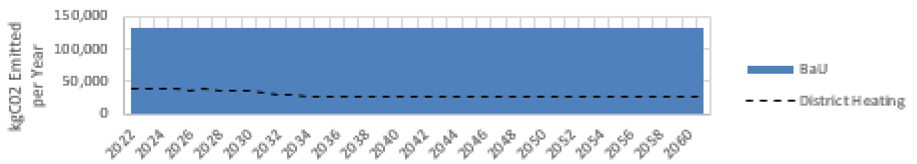
Total Plant Costs:	Total	Av. pence/kWh	Total	Av. pence/kWh	Total Saving
25 Year Costs:	£1,439,369	9.26	£1,439,369	£9.26	0.00%
30 Year Costs:	£1,730,500	9.28	£1,730,500	£9.28	0.00%
40 Year Costs:	£2,310,056	9.29	£2,310,056	£9.29	0.00%



C02 Emissions

Current C02 Emissions			District Heating C02 Emissions		
Total C02 Emissio Total		kgC02/kWh	Total	kgC02/kWh	Total Saving
25 Year C02 Emissions:	3,318,684	0.214	754,506	0.049	77.26%
30 Year C02 Emissions:	3,982,420	0.214	881,173	0.047	77.87%
40 Year C02 Emissions:	5,309,894	0.214	1,134,507	0.046	78.63%

	2022	2062		2022	2062
% Saving vs 1990 Levels:			% Saving vs 1990 Levels:		



Assembly Hall

Building / Estate ID:	Assembly Hall
Residential / Non-Residential:	Non-Residential
Existing or Future Development:	Existing
Modelled Connection Date:	2022
Annual Heat Demand:	369,041 kWh

Heat

System Details

Counterfactual Technology:	Gas Boilers	Technology:	District Heating Connection
Fuel Type:	Gas	Building as a % of Total	
Modelled Plant Size:	120 kW	District Heating Network Load:	16.88%
Plant Generational Efficiency:	86%		

CapEx

BaU / Current Costs		District Heating Connection Costs	
New Plant or Upgrade Installation Costs:		**Network Connection Fee:**	
Generational Plant:	£0	Discount Offered vs Counterfactual:	25%
Secondary Side Systems (In Building):	£0		
Gas Network Development:	£0		
Total Heating System CapEx:	**£0**	Total District Heating Connection Fee:	**£0**

OpEx

Running Costs:

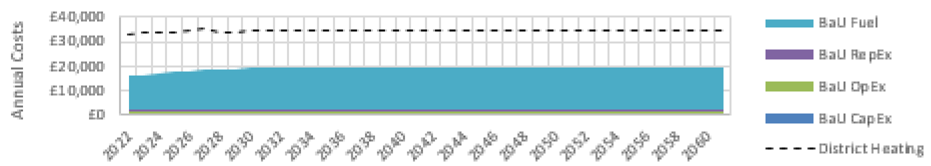
Running Costs:	2022	2062
Discount Offered vs Counterfactua	0%	
Blended Heat Tarff per kWh:	8.94	9.30
Total / year:	**£33,002**	**£34,305**

	Total	Av. pence/kWh		Total	pence/kWh
25 Year Costs:	£854,480	9.26	25 Year Costs:	£854,480	9.26
30 Year Costs:	£1,027,309	9.28	30 Year Costs:	£1,027,309	9.28
40 Year Costs:	£1,371,362	9.29	40 Year Costs:	£1,371,362	9.29

(increase in costs annually due to real price inflation of fuels)

TotEx

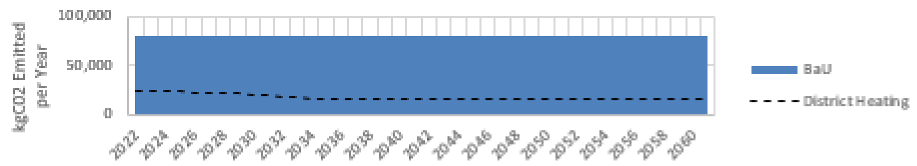
Total Plant Costs:	Total	Av. pence/kWh	Total	Av. pence/kWh	Total Saving
25 Year Costs:	£854,480	9.26	£854,480	£9.26	0.00%
30 Year Costs:	£1,027,309	9.28	£1,027,309	£9.28	0.00%
40 Year Costs:	£1,371,362	9.29	£1,371,362	£9.29	0.00%



C02 Emissions

Current C02 Emissions			District Heating C02 Emissions		
Total C02 Emissio Total		kgC02/kWh	Total	kgC02/kWh	Total Saving
25 Year C02 Emissions:	1,970,132	0.214	447,912	0.049	77.26%
30 Year C02 Emissions:	2,364,159	0.214	523,107	0.047	77.87%
40 Year C02 Emissions:	3,152,212	0.214	673,499	0.046	78.63%

	2022	2062		2022	2062
% Saving vs 1990 Levels:			% Saving vs 1990 Levels:		



Portland House

Building / Estate ID:	Portland House
Residential / Non-Residential:	Non-Residential
Existing or Future Development:	Existing
Modelled Connection Date:	2022
Annual Heat Demand:	181,050 kWh

Heat

System Details

Counterfactual Technology:	Gas Boilers	Technology:	District Heating Connection
Fuel Type:	Gas	Building as a % of Total	
Modelled Plant Size:	450 kW	District Heating Network Load:	8.28%
Plant Generational Efficiency:	86%		

CapEx

BaU / Current Costs		District Heating Connection Costs	
New Plant or Upgrade Installation Costs:		**Network Connection Fee:**	
Generational Plant:	£0	Discount Offered vs Counterfactual:	25%
Secondary Side Systems (In Building):	£0		
Gas Network Development:	£0		
Total Heating System CapEx:	**£0**	Total District Heating Connection Fee:	**£0**

OpEx

Running Costs:

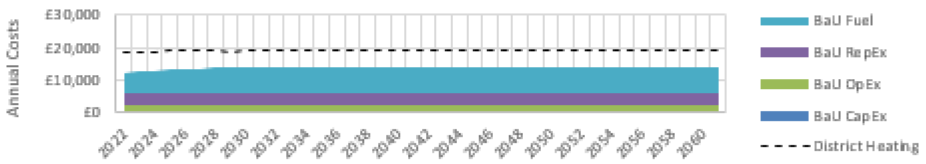
Running Costs:	2022	2062
Discount Offered vs Counterfactua	0%	
Blended Heat Tariff per kWh:	10.25	10.53
Total / year:	**£18,550**	**£19,065**

	Total	Av. pence/kWh		Total	pence/kWh
25 Year Costs:	£475,376	10.50	25 Year Costs:	£475,376	10.50
30 Year Costs:	£571,215	10.52	30 Year Costs:	£571,215	10.52
40 Year Costs:	£762,259	10.53	40 Year Costs:	£762,259	10.53

[increase in costs annually due to real price inflation of fuels]

TotEx

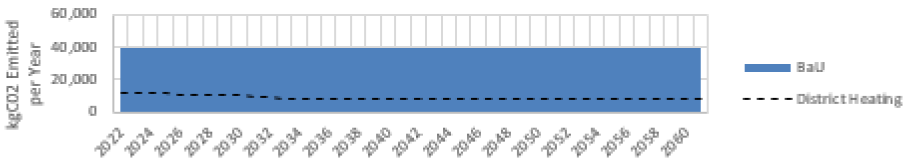
Total Plant Costs:	Total	Av. pence/kWh	Total	Av. pence/kWh	Total Saving
25 Year Costs:	£475,376	10.50	£475,376	£10.50	0.00%
30 Year Costs:	£571,215	10.52	£571,215	£10.52	0.00%
40 Year Costs:	£762,259	10.53	£762,259	£10.53	0.00%



C02 Emissions

Current C02 Emissions			**District Heating C02 Emissions**		
Total C02 Emissio	Total	kgC02/kWh	Total	kgC02/kWh	Total Saving
25 Year C02 Emissions:	966,540	0.214	219,744	0.049	77.26%
30 Year C02 Emissions:	1,159,848	0.214	256,635	0.047	77.87%
40 Year C02 Emissions:	1,546,464	0.214	330,416	0.046	78.63%

	2022	2062		2022	2062
% Saving vs 1990 Levels:			% Saving vs 1990 Levels:		



Museum and Art Gallery

Building / Estate ID:	Museum & Art Gallery
Residential / Non-Residential:	Non-Residential
Existing or Future Development:	Existing
Modelled Connection Date:	2022
Annual Heat Demand:	201,700 kWh

Heat

System Details

Counterfactual Technology:	Gas Boilers	Technology:	District Heating Connection
Fuel Type:	Gas	Building as a % of Total	
Modelled Plant Size:	120 kW	District Heating Network Load:	9.22%
Plant Generational Efficiency:	86%		

CapEx

BaU / Current Costs		District Heating Connection Costs	
New Plant or Upgrade Installation Costs:		**Network Connection Fee:**	
Generational Plant:	£0	Discount Offered vs Counterfactual:	25%
Secondary Side Systems (In Building):	£0		
Gas Network Development:	£0		
Total Heating System CapEx:	**£0**	Total District Heating Connection Fee:	**£0**

OpEx

Running Costs:

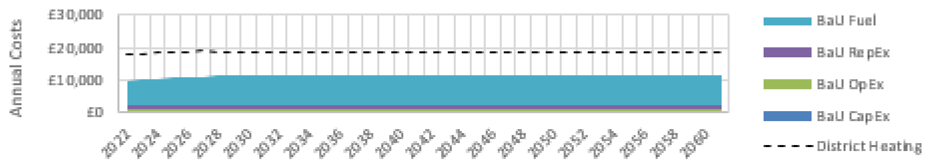
Running Costs:	2022	2062
Discount Offered vs Counterfactua	0%	
Blended Heat Tariff per kWh:	8.96	9.26
Total / year:	**£18,064**	**£18,677**

	Total	Av. pence/kWh		Total	pence/kWh
25 Year Costs:	£465,440	9.23	25 Year Costs:	£465,440	9.23
30 Year Costs:	£559,438	9.25	30 Year Costs:	£559,438	9.25
40 Year Costs:	£746,677	9.25	40 Year Costs:	£746,677	9.25

[increase in costs annually due to real price inflation of fuels]

TotEx

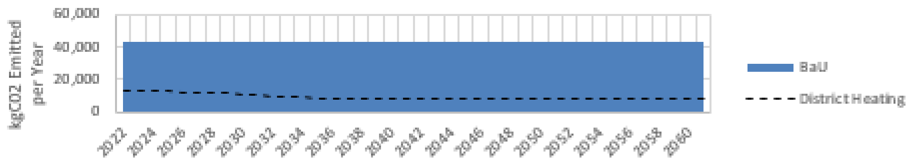
Total Plant Costs:	Total	Av. pence/kWh	Total	Av. pence/kWh	Total Saving
25 Year Costs:	£465,440	9.23	£465,440	£9.23	0.00%
30 Year Costs:	£559,438	9.25	£559,438	£9.25	0.00%
40 Year Costs:	£746,677	9.25	£746,677	£9.25	0.00%



C02 Emissions

Current C02 Emissions			**District Heating C02 Emissions**		
Total C02 Emissio	Total	kgC02/kWh	Total	kgC02/kWh	Total Saving
25 Year C02 Emissions:	1,076,781	0.214	244,807	0.049	77.26%
30 Year C02 Emissions:	1,292,137	0.214	285,906	0.047	77.87%
40 Year C02 Emissions:	1,722,849	0.214	368,103	0.046	78.63%

	2022	2062		2022	2062
% Saving vs 1990 Levels:			% Saving vs 1990 Levels:		



Library

Building / Estate ID:	Library
Residential / Non-Residential:	Non-Residential
Existing or Future Development:	Existing
Modelled Connection Date:	2022
Annual Heat Demand:	153,402 kWh

System Details — Heat

Counterfactual Technology:	Gas Boilers	Technology:	District Heating Connection
Fuel Type:	Gas	Building as a % of Total	
Modelled Plant Size:	300 kW	District Heating Network Load:	7.02%
Plant Generational Efficiency:	86%		

CapEx

BaU / Current Costs		District Heating Connection Costs	
New Plant or Upgrade Installation Costs:		**Network Connection Fee:**	
Generational Plant:	£0	Discount Offered vs Counterfactual:	25%
Secondary Side Systems (In Building):	£0		
Gas Network Development:	£0		
Total Heating System CapEx:	**£0**	Total District Heating Connection Fee:	**£0**

OpEx

Running Costs:

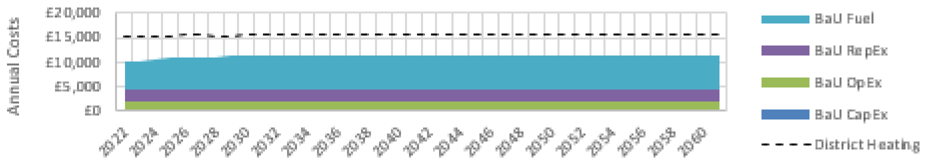
Running Costs:	2022	2062
Discount Offered vs Counterfactua	0%	
Blended Heat Tarff per kWh:	9.85	10.06
Total / year:	**£15,103**	**£15,429**

	Total	Av. pence/kWh		Total	pence/kWh
25 Year Costs:	£385,004	10.04	25 Year Costs:	£385,004	10.04
30 Year Costs:	£462,498	10.05	30 Year Costs:	£462,498	10.05
40 Year Costs:	£617,047	10.06	40 Year Costs:	£617,047	10.06

(increase in costs annually due to real price inflation of fuels)

TotEx

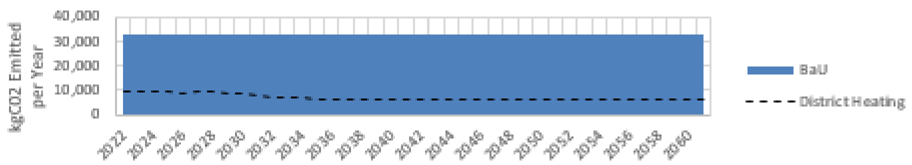
Total Plant Costs:	Total	Av. pence/kWh	Total	Av. pence/kWh	Total Saving
25 Year Costs:	£385,004	10.04	£385,004	£10.04	0.00%
30 Year Costs:	£462,498	10.05	£462,498	£10.05	0.00%
40 Year Costs:	£617,047	10.06	£617,047	£10.06	0.00%



C02 Emissions

Current C02 Emissions			District Heating C02 Emissions		
Total C02 Emissio	Total	kgC02/kWh	Total	kgC02/kWh	Total Saving
25 Year C02 Emissions:	818,942	0.214	186,187	0.049	77.26%
30 Year C02 Emissions:	982,730	0.214	217,445	0.047	77.87%
40 Year C02 Emissions:	1,310,307	0.214	279,959	0.046	78.63%

	2022	2062		2022	2062
% Saving vs 1990 Levels:			% Saving vs 1990 Levels:		



Law Courts

Building / Estate ID:	Law Courts
Residential / Non-Residential:	Non-Residential
Existing or Future Development:	Existing
Modelled Connection Date:	2022
Annual Heat Demand:	350,835 kWh

System Details — Heat

Counterfactual Technology:	Gas Boilers	Technology:	District Heating Connection
Fuel Type:	Gas	Building as a % of Total	
Modelled Plant Size:	600 kW	District Heating Network Load:	16.04%
Plant Generational Efficiency:	90%		

CapEx

BaU / Current Costs		District Heating Connection Costs	
New Plant or Upgrade Installation Costs:		**Network Connection Fee:**	
Generational Plant:	£0	Discount Offered vs Counterfactual:	25%
Secondary Side Systems (In Building):	£0		
Gas Network Development:	£0		
Total Heating System CapEx:	**£0**	Total District Heating Connection Fee:	**£0**

OpEx

Running Costs:

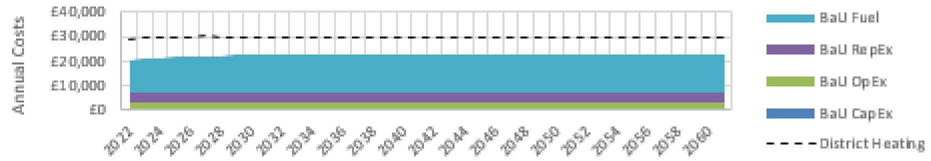
Running Costs:	2022	2062
Discount Offered vs Counterfactua	0%	
Blended Heat Tarff per kWh:	8.29	8.49
Total / year:	**£29,071**	**£29,801**

	Total	Av. pence/kWh		Total	pence/kWh
25 Year Costs:	£743,385	8.48	25 Year Costs:	£743,385	8.48
30 Year Costs:	£893,162	8.49	30 Year Costs:	£893,162	8.49
40 Year Costs:	£1,191,756	8.49	40 Year Costs:	£1,191,756	8.49

(increase in costs annually due to real price inflation of fuels)

TotEx

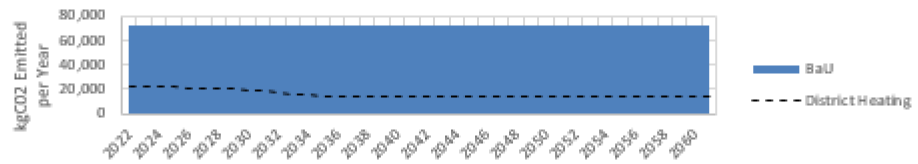
Total Plant Costs:	Total	Av. pence/kWh	Total	Av. pence/kWh	Total Saving
25 Year Costs:	£743,385	8.48	£743,385	£8.48	0.00%
30 Year Costs:	£893,162	8.49	£893,162	£8.49	0.00%
40 Year Costs:	£1,191,756	8.49	£1,191,756	£8.49	0.00%



C02 Emissions

Current C02 Emissions			District Heating C02 Emissions		
Total C02 Emissio	Total	kgC02/kWh	Total	kgC02/kWh	Total Saving
25 Year C02 Emissions:	1,789,700	0.204	425,815	0.049	76.21%
30 Year C02 Emissions:	2,147,640	0.204	497,302	0.047	76.84%
40 Year C02 Emissions:	2,863,520	0.204	640,274	0.046	77.64%

	2022	2062		2022	2062
% Saving vs 1990 Levels:			% Saving vs 1990 Levels:		



WICC Site (NHS Clinic)

Building / Estate ID:	WICC
Residential / Non-Residential:	Non-Residential
Existing or Future Development:	Future
Modelled Connection Date:	2022
Annual Heat Demand:	308,916 kWh

Heat

System Details

Counterfactual Technology:	Air Source Heat Pump	Technology:	District Heating Connection
Fuel Type:	Electricity	Building as a % of Total	
Modelled Plant Size:	116 kW	District Heating Network Load:	14.13%
Plant Generational Efficiency:	339%		

CapEx

BaU / Current Costs		District Heating Connection Costs	
New Plant or Upgrade Installation Costs:		**Network Connection Fee:**	
Generational Plant:	£81,483	Discount Offered vs Counterfactual:	25%
Secondary Side Systems (In Building):	£0		
Gas Network Development:	£0		
Total Heating System CapEx:	**£81,483**	Total District Heating Connection Fee:	**£61,112**

OpEx

Running Costs:

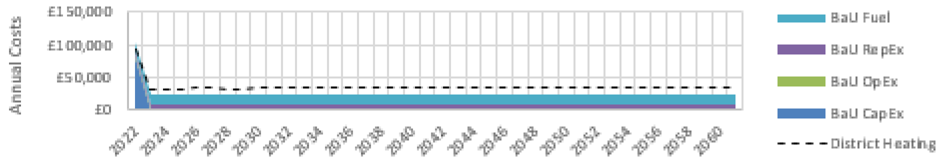
Running Costs:	2022	2062
Discount Offered vs Counterfactua	0%	
Blended Heat Tariff per kWh:	10.38	10.72
Total / year:	**£32,055**	**£33,121**

	Total	Av. pence/kWh		Total	pence/kWh
25 Year Costs:	£825,452	10.69	25 Year Costs:	£825,452	10.69
30 Year Costs:	£992,123	10.71	30 Year Costs:	£992,123	10.71
40 Year Costs:	£1,324,152	10.72	40 Year Costs:	£1,324,152	10.72

(increase in costs annually due to real price inflation of fuels)

TotEx

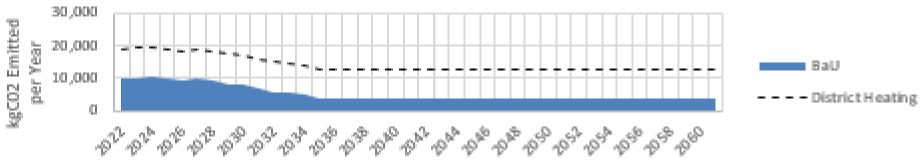
Total Plant Costs:	Total	Av. pence/kWh	Total	Av. pence/kWh	Total Saving
25 Year Costs:	£906,934	11.74	£886,563	£11.48	2.25%
30 Year Costs:	£1,073,605	11.58	£1,053,235	£11.36	1.90%
40 Year Costs:	£1,405,634	11.38	£1,385,264	£11.21	1.45%



CO2 Emissions

Current CO2 Emissions			District Heating CO2 Emissions		
Total CO2 Emissio Total		kgCO2/kWh	Total	kgCO2/kWh	Total Saving
25 Year CO2 Emissions:	151,453	0.020	374,938	0.049	-147.56%
30 Year CO2 Emissions:	170,238	0.018	437,883	0.047	-157.22%
40 Year CO2 Emissions:	207,808	0.017	563,772	0.046	-171.29%

	2022	2062		2022	2062
% Saving vs 1990 Levels:			% Saving vs 1990 Levels:		



Appendix K – Further Optimisation / Sensitivity Analysis

In addition to the base-case sensitivities investigated within the optioneering analysis, additional models have been run to investigate ways to optimise the base solutions. Each sensitivity has been tested in isolation to investigate its impact.

To simplify the level of information presented, only the results based on 'medium-case' heat tariffs are shown here. The LZC plant selection is the same with and without each sensitivity.

K.1 Inclusion of Union Place Development

As detailed in Section 1, there is the opportunity for the additional connection of the Union Place development to the DEN. This shall increase the amount of heat demand on the network, therefore increasing the generation plant sizes and buried network lengths.

The impact of undertaking these works on the economic assessment of the 11 different technical scenarios are shown below:

Scenario	Unfunded IRR without / with sensitivity	Scheme viability and improvements possible as a result of IRR changes
1: OL-GSHP with boilers	1.53% / 8.3%	More LZC, lower tariffs and save more CO_2
2: OL-GSHP with CHP and boilers	4.12% / 8.3%	More LZC, lower tariffs and save more CO_2
3: CL-GSHP with boilers	1.59% / 8.16%	More LZC, lower tariffs and save more CO_2
4: CL-GSHP with CHP and boilers	2.49% / 6.4%	More LZC, lower tariffs and save more CO_2
5: CL-GSHP only	-6.59% / 1.73%	Scheme IRR becomes positive
6: SSHP with boilers	-11.51% / -0.12%	Scheme still not viable (negative IRR)
7: SSHP with CHP and boilers	2.69% / 6.62%	More LZC, lower tariffs and save more CO_2
8: SSHP only	n/a / -0.59%	Scheme still not viable (negative IRR)
9: ASHP with boilers	1.57% / 8.66%	More LZC, lower tariffs and save more CO_2
10: ASHP with CHP and boilers	3.54% / 7.44%	More LZC, lower tariffs and save more CO_2
11: ASHP only	-5.69% / 4.65%	Scheme becomes viable

Table K1-1: IRR and CO2 saving impact as a result of including Union Place on the DEN

The analysis shows that, although the inclusion of additionally connecting Union Place

- Increases thermal demand on the network by approximately 50%;
- Increases the number of viable technical solutions; and
- Increases both capital and operational costs, but also overall profitability of the scheme, thus enabling increase to both the project rate of return and gross carbon savings.

However, including the Union Place on the network will increase the level risk associated with the development of the core network, in terms of:

- technical risk associated with the lead low zero carbon solution having to provide 50% more thermal energy than when only serving the Civic Quarter site;
- programming risk associated with need to develop a minimum of three projects (the DEN, WICC site and Union Place) in parallel with one another; and
- deliverability risk associated with the requirement to work with multiple additional developers, all of whom are likely to be from within the private sector.

K.2 Low Distribution Temperature and Adapted Building Internal Systems

Section 6.3 discussed the possible implementation strategy to lower the internal building heating system flow and return temperatures to increase the generational efficiency of any heat pump system.

The total additional capital cost associated with these works are estimated at approximately £500,000. They enable the lowering of the flow and return temperatures of the network, resulting in the following heat pump efficiency gains:

Heat Pump Plant	CoP, high temp	CoP, low temp	Reduction in scheme fuel costs
OL-GSHP	2.9	3.7	17 – 20%
CL-GSHP	2.9	3.6	17 – 20%
SSHP	3.1	4.1	17 – 21%
ASHP	2.3	2.9	16 – 18%

Table K2-1: Heat pump CoP improvements and fuel cost reductions from lowering Civic Quarter building temperatures

The impact of undertaking these works on the environmental and economic assessment of the 11 different technical scenarios are shown below:

Scenario	Unfunded IRR without / with sensitivity	Potential scheme changes from IRR changes
1: OL-GSHP with boilers	1.53% / 2%	More LZC, lower tariffs and save more CO_2
2: OL-GSHP with CHP & boilers	4.12% / 3.48%	n/a
3: CL-GSHP with boilers	1.59% / 1.56%	More CO_2 saved
4: CL-GSHP with CHP & boilers	2.49% / 2.21%	n/a
5: CL-GSHP only	-6.59% / -3.12%	Scheme still not viable (negative IRR)
6: SSHP with boilers	-11.51% / -5.34%	Scheme still not viable (negative IRR)
7: SSHP with CHP & boilers	2.69% / 2.27%	n/a
8: SSHP only	n/a / -6.51%	Scheme still not viable (negative IRR)
9: ASHP with boilers	1.57% / 1.64%	Lower tariffs & save more CO_2
10: ASHP with CHP & boilers	3.54% / 3.08%	n/a
11: ASHP only	-5.69% / -1.33%	Scheme still not viable (negative IRR)

Table K2-2: IRR and CO2 saving impact as a result of lowering Civic Quarter building temperatures

The analysis shows that, although the adaptation of the buildings comes at an additional capital cost, for the majority of schemes it reduces the overall primary fuel cost and subsequently increases both the project rate of return and carbon performance.

However, as the heat fraction from the heat pumps is smaller in the options that include CHP, the overall IRR is reduced as there isn't as much benefit to the operation of CHP from lowering output temperatures.

Undertaking works to lower the heating flow temperatures will increase the level risk associated with the development of the core network, in terms of:

- technical risk associated with unforeseen problems arising from working on existing building internal systems;
- programming risk associated with additional project elements;
- deliverability risk associated with the requirement to work with multiple additional stakeholders.

K.3 Inclusion of a Cooling Network

As detailed within Section 2, 4 of the building within the Civic Quarter have centralised cooling systems, which are suited to connection into a district cooling network.

As all of the base scenarios investigated have heat-pump plant included to generate hot water, there is also the potential to capture and distribute cooled water. When a heat pump operates in heating mode, waste coolth energy is generated, and vice versa, termed 'prosuming'. In such a system, this waste energy is recovered within the EC and distributed via the appropriate network, increasing the effective efficiency of the heat pump plant. Such a system can be termed as a '4th Generation DEN with prosuming' – more details can be found in Appendix G.

This analysis has assumed that the cooling supply will not be a resilient supply, as minimal additional space is available within the preferred energy centre locations. Therefore, all sites that are supplied cooling would be required to retain their existing cooling plant to ensure resilient operation. The cooling tariff has set to take this into account.

The impact of undertaking these works on the environmental and economic assessment of the 11 different technical scenarios are shown below:

Scenario	Unfunded IRR without / with sensitivity	Scheme viability & improvements possible as a result of IRR changes
1: OL-GSHP with boilers	1.53% / 1.26%	Slightly less LZC, CO_2 savings the same
2: OL-GSHP with CHP & boilers	4.12% / 3.93%	Slightly less LZC, CO_2 savings the same
3: CL-GSHP with boilers	1.59% / 1.32%	Slightly less LZC, CO_2 savings the same
4: CL-GSHP with CHP & boilers	2.49% / 2.38%	Slightly less LZC, CO_2 savings the same
5: CL-GSHP only	-6.59% / -6.24%	Scheme still not viable (negative IRR)
6: SSHP with boilers	-11.51% / -10.07%	Scheme still not viable (negative IRR)
7: SSHP with CHP & boilers	2.69% / 2.68%	Slightly less LZC, CO_2 savings the same
8: SSHP only	n/a	Scheme still not viable (negative IRR)
9: ASHP with boilers	1.57% / 1.27%	Slightly less LZC, CO_2 savings the same
10: ASHP with CHP & boilers	3.54% / 3.37%	Slightly less LZC, CO_2 savings the same
11: ASHP only	-5.69% / -5.24%	Scheme still not viable (negative IRR)

Table K3-1: IRR and CO_2 saving impact as a result of including a cooling network

The analysis shows that the inclusion of a cooling network:

- comes at an additional capital cost which outweighs the increased overall revenue collection to the scheme; and
- increases the overall scheme heat pump efficiency, however as the delivered coolth is displacing electrically powered high efficiency chiller plant, CO_2 savings are not as significant as the heat network, which displaces much 'dirtier' gas fuelled boiler plant.

This results in a reduction to the project rate of return and a small improvement to the carbon performance.

Should cooling demand on site increase in the future, then it is possible to install such a system a later date as it required very little adaptation of the existing plant and a relatively small amount of additional buried pipework.

However, including a cooling network will increase the level risk associated with the development of the core network, in terms of:

- technical risk associated with the need to install more buried pipework across the site;
- operational risk associated with operating dual networks.

K.4 Switching to Green Gas Tariffs

The optioneering study includes 4 potential solutions that include the inclusion of gas-fired CHP plant, which has, in the base case scenarios, shown to result in higher unfunded IRRs in comparison to heat-pump only options; whilst lowering the overall scheme CO_2 emission savings, as the gas is not expected to decarbonise in comparison the power grid network.

To increase the levels of carbon savings achieved by these schemes, it is possible for the network to enter into a Private Purchase Agreement (PPA) with a bio-gas supplier who supply the gas grid network with 'green gas'. This is typically produced through Anaerobic Digestion (AD). This gas has the benefit of being low or zero carbon as a result of its means of production, with unit prices being roughly 3 - 4 times that of natural gas (at the time of writing). In reality, the actual unit price is subject to a direct commercial agreement between then scheme and biogas producer(s) and is therefore highly variable.

The impact of undertaking these works on the environmental and economic assessment of the 11 different technical scenarios are shown below:

Scenario	Unfunded IRR without / with sensitivity	Scheme viability & improvements possible as a result of IRR changes
2: OL-GSHP with CHP & boilers	4.12% / na	Scheme no longer viable (negative IRR)
4: CL-GSHP with CHP & boilers	2.49% / na	Scheme no longer viable (negative IRR)
7: SSHP with CHP & boilers	2.69% / na	Scheme no longer viable (negative IRR)
10: ASHP with CHP & boilers	3.54% / na	Scheme no longer viable (negative IRR)

Table K4-1: IRR and CO_2 saving impact as a result of switching to a 'green gas' certification scheme

The analysis shows that, through the use of 'green gas' on site, all schemes present negative IRRs, although the levels of CO_2 reduction are close to 100%.

Planning for the use of a green gas tariff will increase the level of risk associated with:

- Economic risk associated with the variability of the PPA contracts available for such a scheme, with direct agreements required between the DEN and a producer of biogas; and
- Economic risk associated with the short-term nature of PPA agreements, which can typically be as short as 3 years in length.

K.5 Alterations to Optioneering Ranking & Summary

The table below details the impact of each sensitivity scenario investigated:

Sensitivity	Effect on base scheme economic viability	Effect on base scheme carbon savings	Recommendation
Inclusion of Union Place	Improvement	Improvement	Include in scheme
Lowering of building temperatures	Improvement	Improvement	Include in scheme
Inclusion of a cooling network	Reduction	Improvement	Exclude from scheme
Switching to green gas tariffs	Reduction	Improvement	Exclude from scheme

Table K5-1: Outcome from sensitivity analysis

The overall benefit to scheme economic and environmental performance of including both Union place and lowering of building temperatures to the scheme are stacked, resulting in the following optioneering results:

Scenario	Unfunded IRR without / with sensitivities	Scheme viability & improvements possible as a result of IRR changes
1: OL-GSHP with boilers	1.53% / 10.15%	More LZC, lower tariffs & save more CO_2
2: OL-GSHP with CHP & boilers	4.12% / 9.28%	More LZC, lower tariffs & save more CO_2
3: CL-GSHP with boilers	1.59% / 9.53%	More LZC, lower tariffs & save more CO_2
4: CL-GSHP with CHP & boilers	2.49% / 7.44%	More LZC, lower tariffs & save more CO_2
5: CL-GSHP only	-6.59% / 4.18%	Scheme IRR becomes positive
6: SSHP with boilers	-11.51% / 1.71%	Scheme IRR becomes positive
7: SSHP with CHP & boilers	2.69% / 7.32%	More LZC, lower tariffs & save more CO_2
8: SSHP only	n/a / 1.52%	Scheme IRR becomes positive
9: ASHP with boilers	1.57% / 10.25%	More LZC, lower tariffs & save more CO_2
10: ASHP with CHP & boilers	3.54% / 8.58%	More LZC, lower tariffs & save more CO_2
11: ASHP only	-5.69% / 8.06%	Scheme IRR becomes positive

Table K5-2: IRR and CO_2 saving impact as a result of including Union Place on the DEN

The table above shows that, with both the inclusion of the Union Place development and the lowering of the building heating system temperatures, all technical solutions become economically viable (assuming heat tariffs in accordance with gas boiler operation and social cost).

Of particular note is that the SSHP (with or without gas boilers) options become economically viable under this scenario. As SSHP is considered deliverable (from a technical perspective, see Appendix F), this option has been taken forward for further development within the main body of the report.

Appendix L – Generated Drawings

A full drawing pack has been supplied to WBC as a separate document as part of the completion of this study.

Appendix M – Risk Register

A full risk register has been supplied to WBC as a separate document as part of the completion of this study.

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